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STATISTICAL ANALYSIS OF NAVAL AVIATION DEPOT REPAIR CYCLE TIME REDUCTION FOR THE F/A-18 C/D AIRCRAFT

by

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June 2001

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STATISTICAL ANALYSIS OF NAVAL AVIATION DEPOT REPAIR CYCLE TIME REDUCTION FOR THE F/A-18 C/D AIRCRAFT

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Reducing U.S. Navy inventory control problems associated with the F/A-18 C/D aircraft is critical to maintaining squadron readiness while minimizing procurement and repair costs. The Navy's Inventory Control Point has designed its Carcass Express program to ensure that critically short depot level repairables are serviced more quickly. The program was initiated on the S-3 Viking aircraft in 1999. Subsequently, the number of constrained carcasses was reduced by 40 percent, and the average depot repair cycle time was reduced by 12 days. This thesis attempts to quantify the savings that can be realized by instituting the Carcass Express program for the F/A-18 C/D. Data for F/A-18 C/D repairable items that were identified as having insufficient carcasses for repair to meet current demand levels are analyzed. These repairable items have high dollar values and significant backorders severely impacting squadron readiness.

It is shown that the Carcass Express program would provide an additional accrual of inventory over a four-year period for the items studied. The required funding needed to support the deficit between items available from the depot repair cycle and forecast quarterly demands would decrease. The Carcass Express initiative would improve the predictability of the Depot Repair Cycle by reducing repair cycle variability. This ultimately would lead to better inventory management.

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Submitted in partial fulfillment of the
requirements for the degree of

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LIST OF ACRONYMS

AIMD	Aviation Intermediate Maintenance Depot
ASO	Aviation Supply Office
ATAC	Advanced Traceability and Control
BCM	Beyond Capability of Maintenance
DD	Defense Depot
DDC	Defense Distribution Center
D-LEVEL	Depot Level
DLR	Depot Level Repairable
DMRD	Defense Management Review Decision
DOD	Department of Defense
DOP	Designated Overhaul Point
DSP	Designated Support Point
FEDLOG	Federal Logistics Library
FIC	Family Identification Code
FISC	Fleet Industrial Supply Center
FLR	Field Level Repairable
FMC	Full Mission Capable
FSC	Federal Supply Class
FY	Fiscal Year
FSG	Federal Supply Group
G-CONDITION	Awaiting Parts
I LEVEL	Intermediate Level
IM	Item Manager
LMI	Logistics Management Institute
LRT	Logistics Response Time
M-CONDITION	Undergoing Maintenance
MOE	Measure of Effectiveness
MRIL	Master Repairable Item List
NADEP-NI	Naval Aviation Depot – North Island
NAVAIR	Naval Air Systems Command
NAVICP-M	Naval Inventory Control Point, Mechanicsburg, PA
NAVICP-P	Naval Inventory Control Point, Philadelphia, PA
NAVSUP	Naval Supply Systems Command.
NIIN	National Item Identification Number
NMCS	Not Mission Capable Supply
NPS	Naval Postgraduate School
NRFI	Not Ready For Issue
NSN	Navy Stock Number
O-LEVEL	Organizational Level
PMCS	Partially Mission Capable Supply
RFI	Ready For Issue
RTAT	Repair Turnaround Time
SD	Standard Deviation
SPCC	Ships Parts Control Center
UIC	Unit Identification Code
UICP	Uniform Inventory Control Program

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GLOSSARY

Backorder	A request from a customer that cannot be immediately satisfied and is held in suspense until the materiel to satisfy the request is received by the supply system.
Carcass	A failed repairable unit.
Carcass returns	The number of failed units returned to the supply system for repair during a given time period.
Cognizance symbol	A two-position code denoting the Inventory Control Point that manages the item and the type of item.
Consumable item	An item that when it fails in use, it cannot be economically repaired.
Demand	The number of units of an item requested by a customer in a given time period.
Depot Level Repairable item	An item that when it fails in use is returned to the Navy wholesale supply system for repair.
Depot Repair Cycle	The amount of time measured from the determination that a failed DLR item is beyond local maintenance activity repair capability until the item is repaired and recorded as inventory by NAVICP.
Deviation	Measure of forecast accuracy
Direct Demand	Demand created when a DLR item fails in the field
Exponential smoothing	A mathematical averaging technique that assigns a positive weight to both the current observation and the previous forecast, where the sum of the weights equals one.
Forecast Demand	The UICP model predicted quarterly demand.
Induction	The entering of items into the repair process.
Inventory Control Point	An activity having wholesale inventory management responsibilities for a group of items.
Item Manager	An employee of an inventory control point who is responsible for the overall inventory management of a particular item.
Material Condition Code	A single alpha code that indicates the various states of RFI or NRFI of on-hand assets in the supply system.

Net Price	The price charged for a new item when the failed DLR carcass is returned for repair.
Procurement Lead Time	The length of time from generation of a procurement action until the initial receipt of material from contract.
Repair Completion Date	The date of repair completion. The date the designated overhaul point transfers custody of the overhauled item to a stock point.
Repair Cycle Time	The length of time represented by the Depot Repair Level Turnaround Time plus the time period between repair scheduling.
Ready-for-Issue Asset	A unit that can be immediately provided to meet customer requests for an item.
Recurring Demand	Demand of a random nature that is expected to occur over and over.
Repair Time	RTAT. The amount of time an item spends in repair. Includes actual repair time plus time waiting for repair.
Repair Price	The price paid to repair an item.
Retrograde Segment	Local processing and transportation to a maintenance repair facility.
Repair Turnaround Segment	Collective sum of the actual maintenance time
Safety Level	The amount of stock levels maintained to provide "stockout protection" against the variability of lead-time demand or depot level turnaround time demand.
Standard Deviation	A mathematical measure of the variability of observations about their mean (average) value.
Standard Price	The price paid for a new or overhauled item.
Uniform Inventory Control Program	A series of computer files and programs used by NAVICP to manage wholesale supply system inventories.
Variance	A mathematical measure of the variability of observations about their mean (average) value. Variance is the square of the standard deviation.

EXECUTIVE SUMMARY

The military readiness of the F/A-18 C/D has been degraded because of the increasing number of repair components in a backorder status. Repaired components are a valuable inventory source. However, the availability of carcasses for many of these components is severely limited. The Naval depot repair facilities can only effect repairs on components that have a stock of carcasses. To address the readiness issue, the Naval Inventory Control Point (NAVICP) initiated a program to ship failed depot level repairable (DLR) items exhibiting a shortage of carcasses directly to the repair facility. The program, known as Carcass Express, was initiated in 1999 on 45 DLR items for the S-3 Viking aircraft. Within a year, 40 percent of these DLR items no longer exhibited a carcass shortage. In addition, the depot repair cycle time, which consists of the amount of time it takes for a failed DLR item to be shipped to the repair facility, repaired, and listed as available inventory, was reduced by 12 days, on average. In light of its success with the S-3, NAVICP decided to implement the Carcass Express program for the F/A-18 C/D. The scope of the F/A-18 C/D program is significantly larger, consisting of more than 1,200 DLR components. The target established by NAVICP for the F/A-18 C/D Depot Repair Cycle is for shipments to average 10 days. This represents a 29-day reduction from the current average cycle shipment time.

The purpose of this thesis is to quantify the savings that can be realized with the Carcass Express program as it applies to the F/A-18 C/D DLR items identified by NAVICP. The data used for analysis were consolidated from the repair turnaround time (RTAT) database and the demand database, maintained by NAVICP, and the

transportation times maintained by NAVTRANS. By linking the three data sets, it was possible to estimate the potential cost savings due to implementation of the Carcass Express program on F/A-18 C/D repairable items.

The research described in this thesis examines the availability of DLR components from the depot repair cycle based on decreasing the amount of transportation time associated with each component. The inventory availability is then compared to two different demand levels, referred to as "forecast demand" and "direct demand." Forecast demand was generated from the automated tool, known as the Uniform Inventory Control Program (UICP), which NAVICP uses to forecast quarterly demand by item. Direct demand originates from the DLR component failure itself. When a DLR fails, it must be replaced on a one-for-one basis, which generates a unit demand for the item. By comparing the two demand levels with the available inventory from repair, the amount of additional inventory required to maintain satisfactory stocking levels can be computed.

This thesis identifies the potential savings achieved by implementing the Carcass Express program. The analysis examines 185 of the 1,200 DLR components identified by NAVICP. These 185 DLRs have sufficient data entries across each of the depot repair cycle segments to conduct a detailed analysis. The increase in capacity to meet quarterly demand specifically from repairs that are registered in inventory the same quarter for these 185 DLR components is greater $28.9 million dollars, measured over a four-year period. Additionally, the analysis showed a substantial reduction in variability for the quarterly DLR items available for inventory from depot level repair. The 185 DLR items were segregated by median transportation times. The high group, consisting of transportation times greater than 20 days, had a 20 percent reduction in variability. The

low group, consisting of transportation times less than or equal to 20 days, had a 9 percent reduction in variability.

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I. INTRODUCTION

A. BACKGROUND

The Unites States Navy classifies its stocks of spare parts as either consumable or repairable. The depot repair cycle for depot-level repairables (DLRs) begins with the determination that a defective item is beyond the repair capability of the local maintenance activities (Department of Defense, 1998). It ends when the item is restored to serviceable condition and is recorded on the inventory control point (ICP) records as being ready-for-issue (Kang, 1998). The depot repair cycle is composed of the *retrograde* segment, consisting of local processing and transportation to a maintenance repair facility, and the *repair turnaround* segment, which is the collective sum of the actual maintenance time. The objective of this thesis is to demonstrate the fiscal impact of expediting the shipment of repairables associated with the F/A-18 C/D aircraft, hereafter referred to as F/A-18, to a repair facility on meeting current demand levels over time.

The duration of the depot repair cycle is important to the Navy for two reasons. First, timely depot repair of failed DLRs is essential to operational readiness and sustainability. For many repairables, depot repair is the most responsive and least-costly option available to support the operating customers' requirements. Second, because of the high unit costs of DLRs, there is a significant inventory investment involved while the parts are being repaired within the depot repair cycle. From Little's formula (Little, 1961), reducing cycle time reduces pipeline inventory directly and proportionally. Cycle time reduction in a military logistics channel means that more weapons systems are

available at the squadrons, and also leads to significant savings in inventory costs (Kang, 1998). The shorter the depot repair cycle time, the smaller the investment in DLRs that must be made available to fill the voids created when a failed DLR is removed for repair. The longer the depot repair cycle time, the more assets will be needed in the supply system to ensure that operations are not interrupted while waiting for unserviceable DLRs to be fixed.

Several recent studies have attempted to quantify the overall cost associated with the duration of the depot repair cycle. Kang (1998) demonstrated that substantial savings to the U.S. Navy could be achieved merely by decreasing repair turnaround time. Department of Defense reports indicate that of the $5.4 billion of on-hand unserviceable DOD assets that should be in maintenance to meet current basic requirements, $2.9 billion, or 53%, had yet to be inducted into the maintenance phase of the repair cycle (Kiebler, 1996). These findings point to a target-rich environment for realizing significant cost savings by reducing the length of the depot repair cycle. To illustrate the potential magnitude of these savings, the Department of Defense wholesale inventory investment in DLR assets was $38.1 billion as of September 1994. Based on 1995 Budget Estimate Submissions (Kiebler, 1996), the average depot repair cycle time was 86.8 days, with a resulting pipeline inventory valued at $4.4 billion. Applying Little's formula, pipeline inventory would be decreased by an average of $51 million for each day the depot repair cycle time is reduced.

Reductions of repair cycle levels do not result in an immediate decrease in required inventory investment. One-time acquisition and repair savings are realized over a number of years and vary within the inventory control point, by the size of the

reduction, by the asset position in relation to the requirements, and by the mix of serviceable and unserviceable assets. In addition to reducing the purchase of new inventory, annual recurring inventory carrying cost reductions associated with the lower inventory will also be realized.

The depot repair cycle is a process consisting of organizational-level and intermediate-level maintenance and supply activities, transportation, distribution depots, inventory control points managing DLRs, depot maintenance activities, and supply activities that support depot maintenance. Quantifying the benefits that result from an improvement to one facet of the repair process, therefore, must address the roles and interfaces among all functions and activities.

Kiebler (1996) recommended that "items in a critical asset position should be automatically returned, expeditiously processed, and express transportation used when appropriate." The depot repair cycle time is defined, as the amount of time from DLR failure to the time that the DLR item is repaired and ready for issue. Figure 1.1 compares the actual, the ICP file, and current standard depot repair cycle times.

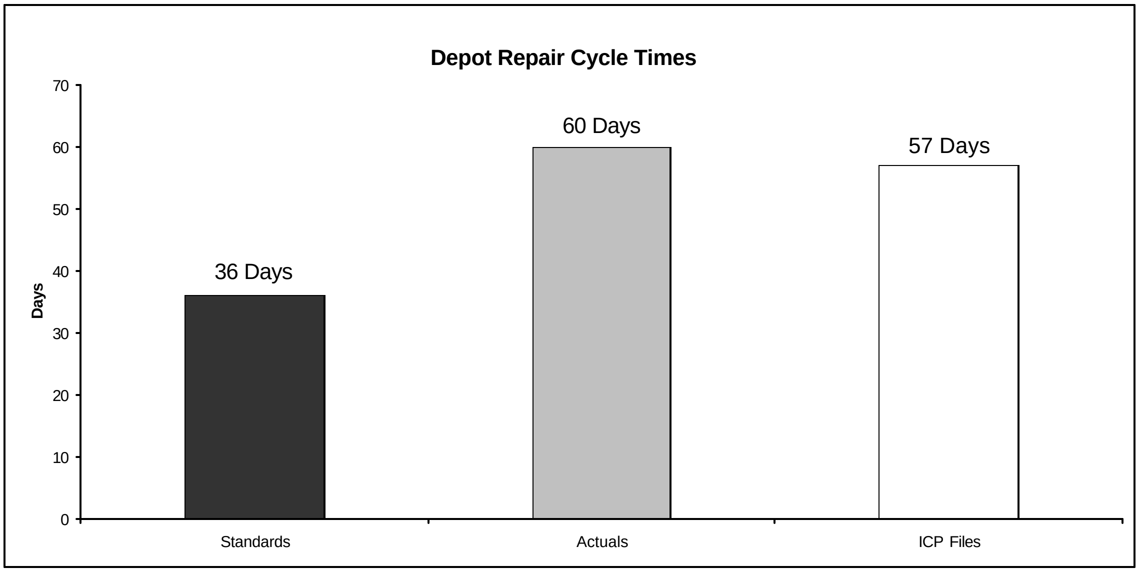

Figure 1.1 Comparison of Standard, Actual and ICP Depot Repair Cycle Times

The average depot repair cycle time for a sample of items was 60 days. The Service ICPs used 57 days as a basis for computation of the repair cycle level. The DOD standard for the sampled items was 36 days, or 37 percent less than that used by the inventory control point. (After: Kiebler, 1996)

Kiebler (1996) found that, if the duration of the depot repair cycle were reduced to that of the DoD standards, a reduction in the repair cycle inventory of about 37 percent would be realized. Applied to the 1995 repair cycle inventory investment of $4.4 billion, this would translate to a $1.6 billion cost savings.

Naval Inventory Control Point, Philadelphia (NAVICP-P) has identified a group of DLR items that are considered to be critical assets to the U.S. Navy Strike–Fighter aircraft, the F/A-18. The F/A-18 has experienced an increasing number of part shortages that have been observed to degrade the operational capabilities of the squadrons (Brown, 2000). In light of these shortages, NAVICP-P instructed Navy personnel to immediately ship any of the unserviceable DLRs on their critical asset list directly to the repair depot, with the goal of reducing the transportation element of the depot repair cycle time to an

average of 10 days. This thesis will examine the impact on Navy inventory management achieved by reducing the average depot repair cycle time to 10 days. The analysis will be facilitated using the statistical software package S-plus. The specific software created for this thesis is shown in Appendix A. It is demonstrated that this reduction in repair cycle time also reduces the amount of variability within the repair cycle and should ultimately minimize inventory investment, provide substantial assets to sustain issues during the repair process, and provide a reliable basis for meeting required delivery dates.

Kiebler (1996) found that a reduction in repair depot cycle time provides a down-stream opportunity for inventory investment reductions and for one-time reductions in procurement and repair requirements. Ideally, as the depot repair cycle demonstrates less variability, the quantity of spare parts required to meet forecast demand levels will become a function of the service life of each specific DLR only. When a DLR is beyond capability of being repaired, a new item must be purchased to replace it.

B. OBJECTIVES OF THE THESIS

This thesis examines a subset of Naval inventory for the F/A –18 represented over the four year period, 1996 through 1999. The subset, consisting of 185 DLR items, constituted an inventory investment over the four-year period of over $900M. Table 1.1 breaks this investment down by component category. This investment represents the total value of repair transactions for each of the 185 DLR items used in this analysis. A repair transaction is defined as a DLR item that was repaired and subsequently made available for issue during the time frame of the analysis.

Table 1.1 Replacement Cost, by Component Category, for 185 DLR Items 1996-1999

Component Category	DLR Items	Dollar Value
Circuit Card Assembly	74	62,929,400
Electrical	52	320,966,620
Mechanical	59	522,714,540
Total	**185**	**$906,610,560**

Dollar value is the sum of inventory available from repair by category over the four-year period at the standard price (FY 2000 U.S. dollars). A complete listing of part numbers and nomenclature is given in Appendix B.

The 185 DLR items are divided into two subgroups for analysis. The two subgroups, illustrated in Appendix B, consisting of DLR items with high and low median transportation times, respectively, were determined from the 1998 transportation times associated with each item within the depot repair cycle. Specifically, the thesis quantifies the effect of reducing the aggregate transportation time associated with each subgroup and attempts to quantify the overall effect of the reduction on meeting current demand levels. Delivering unserviceable parts faster will create a more consistent available inventory and reduce the variability within the repair cycle.

Directing effort to reduce the transportation time of critical Naval aviation parts is a recent concept. A similar process was undertaken by NAVICP-P for the S-3 Viking aircraft. The S-3 Viking is a turbofan aircraft used to hunt and destroy enemy submarines and to provide surveillance of surface shipping. The combination of available inventory, repair pipeline and procurement pipeline could not meet the DLR deficiencies experienced in the S-3 squadrons. NAVICP developed an “express” system to increase the number of serviceable DLRs available to the repair depots. The concept was to expedite a group of DLR items through the depot repair cycle until purchasing and repair could meet the current demand levels. The initial results were favorable. More

unserviceable DLRs arrived at the repair depot than could be inducted. Forty-five DLR items appeared on the NAVICP express list. Within a year, 40 percent of the selected DLR items no longer experienced carcass deficiencies. A greater benefit, perhaps, was the 12-day reduction in average retrograde time (Mueck, 2001).

It is reasonable to anticipate that savings on a scale similar to the S-3 could be realized by reducing the transportation time of F/A-18 repairable items. The objectives of this thesis are as follows:

1. Evaluate the NAVICP demand levels for a period of four years. Quantify the proportion of demand that can be met by reducing transportation times of F/A-18 repairables consistent with the goals of the Carcass Express program.

2. Compare the inventory variability within the current Depot Repair Cycle to that imposed by the Carcass Express program. Demonstrate the variability reduction generated by the Carcass Express program.

C. THESIS OUTLINE

The balance of the thesis is organized as follows. Chapter II presents an overview of Naval Inventory Management and discusses the Naval Component Repair Process. Chapter III details the data characteristics and assumptions. Chapter IV discusses computational details. Chapter V presents conclusions of the thesis.

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II. NAVAL AVIATION REPAIRABLE MANAGEMENT

Aviation support has a rich history, dating back to 1917 with the establishment of the Naval Aircraft Factory at the Philadelphia Naval Shipyard. In order to support the expanding and complex Naval air system, the Aviation Support Office (ASO) was founded on October 1, 1941 with 200 civilian employees and 14 officers at the Naval Aircraft Factory in the Philadelphia Naval Shipyard. Today, the Philadelphia site primarily focuses on aviation and weapon system support. Among the aircraft supported is the F/A-18 as well as various engines, common avionics, and support equipment.

The history of the Ships Parts Control Center (SPCC) dates back to 1944 when the Naval Supply Depot, Mechanicsburg, was directed to form a master control for ships parts. In July 1945, SPCC was established as the single worldwide manager for the mechanical components combined to make a ship and its engines (ships parts). SPCC was officially commissioned on July 24, 1953. By the 1980s, ASO and SPCC had become the two remaining inventory control points providing logistics support to the Navy Fleet.

On October 2, 1995, the Naval Inventory Control Point (NAVICP) was established with the merging of ASO in Philadelphia and SPCC in Mechanicsburg. The purpose of this merger was to bring together all of the Navy's program support inventory control point functions under a single command. The decision to join the activities together under one Command consisting of two sites resulted from the need to reduce costs and infrastructure as well as to standardize inventory management procedures. The current mission of NAVICP is to provide program and supply support for the weapons

systems that keep U.S. Naval forces mission ready (Naval Supply Systems Command (NAVSUP) 2000).

As of 1 December 2000, NAVICP Philadelphia managed approximately 68,800 repairable items known as Depot Level Repairables (DLR) (Ackert 2000). DLRs are items, which are sent to a repair activity upon failure and are typically returned to usable condition at a cost significantly less than the purchase price of a new item and in a time interval substantially shorter than the procurement time of a new item (Maher 1993).

A. OVERVIEW OF NAVY INVENTORY MANAGEMENT

This section describes the infrastructure of Navy Inventory Management, including Navy materiel and the associated classification and identification system, wholesale inventory management within NAVICP, DLR sourcing and the physical distribution system.

1. Navy Inventory System (NIS)

NIS provides end users with "secondary items of supply for weapons, weapons support systems and equipment with aviation or marine applications" (NAVSUP 1996). In this context, NIS manages items at the wholesale level and not items managed by other non-Navy entities such as the General Services Agency or the Defense Logistic Agency. NIS items are divided into two categories: consumables and DLRs (Reich 1999). This thesis will examine only the DLR portion of the NIS.

DLRs are items that are economical to repair but require repair at a depot. Although DLRs make up about half of the total stocked items in the NIS, they are inherently more costly, complex and harder to manage than consumables because as long as the demand exists, they continue to be repaired, restocked and reused until destroyed,

lost or beyond economic repair. DLRs fall into three categories: component parts, end items and modification kits. Component parts are used in combination with other items to make up a system or end item. End items, which are intended for use on a stand-alone basis, are a combination of components, which themselves are DLRs (e.g., planes, ships). Modification kits are a combination of components but are assembled by the systems command (e.g., Naval Air Systems Command). Modification kits are managed by NAVICP and issued as one stock number to customers for use in altering the capability, function or performance of an end item or a component of an end item (NAVSUP 1992).

Every item managed by the Naval Supply System has a National Stock Number (NSN), a 13-digit code that uniquely identifies the item. Parts are ordered through the Naval Supply System by their NSN. NSNs contain both a four digit Federal Supply Class (FSC) and a nine digit National Item Identification Number (NIIN). The FSC identifies the federal materiel category while the NIIN uniquely identifies the part. The FSC is further broken down into a two-digit Federal Supply Group (FSG) and two-digit product class. FSG identifies the major materiel category while product class more narrowly defines the kind of materiel included in the FSG. Each NSN can further be categorized by an associated two-character alphanumeric materiel cognizance symbol (COG), which identifies the organization responsible for its management. A description of an NSN is found in figure 2.1.

DLRs managed by NAVICP are assigned COGs "7E", "7G","7H", "7R", and "7Z". Materiel denoted 7R constitutes the majority of the aviation materiel repaired at a depot level. The Carcass Express program focuses on 7R DLR items. In order to further

segregate the DLR items for analysis, this thesis classifies "7E", "7G", "7H" and "7Z" as non-aviation COGs and "7R" as an aviation COG.

7R-1650-01-110-0736

COG FSG Class NIIN

Figure 2.1 Cognizance Symbol and National Stock Number Example

The item referenced has nomenclature "Actuating Cylinder". The leading digit "7" indicates that the item is a DLR managed by NAVICP. "R" identifies the part as an aviation item. "16" identifies the item as belonging to FSG "Aircraft Components and Accessories". "50" indicates that the item belongs to "Aircraft Hydraulic, Vacuum and Deicing System" Class. The NIIN uniquely identifies the item.

The NIS operates in two echelons: retail consumer level and wholesale level. Retail consumer level activities consume or use retail stocks (consumables and DLRs) to support their own operations. Activities falling into this category include ships, submarines and shore bases. Wholesale activities carry items to support worldwide demand, including replenishment of the retail level and all levels of maintenance. This thesis only considers wholesale DLR management.

2. NAVICP

NAVICP is responsible for maintaining worldwide control and visibility over all U.S. Navy wholesale stock. NAVICP is divided between two geographic sites referred to as NAVICP Mechanicsburg (NAVICP-M) and NAVICP Philadelphia (NAVICP-P). In 1999, NAVICP-M managed roughly 260,000 line items worth \$8.0 billion (including 117,300 DLR line items worth \$7 billion) in support of the surface and subsurface Navy (Reich, 1999). NAVICP-P managed 111,000 line items worth \$21.5 billion (including 68,800 DLR line items worth \$21.0 billion) in support of Naval and Marine Corps Aviation (Ackert, 2000).

NAVICP efforts encompass all aspects of product management including buying, repairing, distributing, issuing and disposing of materiel. Although NAVICP directs distribution and issuance of Navy wholesale materiel, it does not manage any of the distribution activities. Defense Management Review Decision 902 shifted responsibilities for physical distribution from the services to DLA (Holmes, 1994).

NAVICP determines Navy wholesale inventory levels using an adaptation of the "lot reorder point" model described in Hadley and Whitin (1963, Chapter 4). This model is a component of the Uniform Inventory Control Program (UICP) and it is used to determine “optimal” inventory level requirements by minimizing an average annual variable cost. The remainder of the UICP model is composed of order costs, holding costs, and shortage costs (NAVSUP, 1992). UICP is a highly automated, integrated system that, except for provisioning, provides automated application software support for nearly the full range of NAVICP functions, including procurement and financial control (NAVSUP, 1996).

Item managers at NAVICP have the primary responsibility for ensuring that secondary item parts are available to support operations of the fleets, Naval shore activities and other functions (NAVSUP, 1992). At the end of Fiscal Year 1997, NAVICP-M employed 108 item managers and NAVICP-P employed 257 item managers (Patten, 2000). Item managers utilize UICP to determine where to position new procurements or returns from repair. UICP recommends wholesale inventory positioning based on the historical percentage of worldwide Naval demand (i.e., if 25% of worldwide demand is in Norfolk, then 25% of the worldwide inventory should be positioned there). However, item managers may choose to ignore the positioning recommendation if there

are overriding factors. NAVICP requires that Ready-for-Issue DLRs returned from repair depots be positioned at the closest Distribution Depots to minimize transportation cost without regard to projected demand location (Munson, 2000).

3. Maintaining DLRs

DLRs in stock are either new procurements or repaired items. Repaired items originate from one of three sources: manufacturers, government-operated repair depots, or commercially operated repair depots. NAVICP item managers control the procurement of DLRs. With the assistance of UICP demand forecasts and DLR survival rates (a combination of wear-out and survival of the repair process), item managers estimate the quantity of wholesale inventory that is returned to the NIS from repair, and the quantity of new inventory that must be procured.

Each DLR has a designated overhaul point (DOP) for restoring an unserviceable component to a fully serviceable condition. The Master Repairable Index List (MRIL) is a database within UICP that identifies the DOP associated with a particular DLR. There are three types of DOPs: organic, commercial, and non-Navy DoD. Organic DOPs are Naval repair activities such as Naval Aviation Depots (NADEPs), Naval Weapons Stations, and Naval shipyards. Commercial DOPs are non-governmental activities, often the manufacturers of the item. Non-Navy DoD facilities are those associated with the other Services such as the Air Force Air Logistics Centers.

The NADEPs have the capability to perform nearly every facet of aviation related component repair. Currently, the Navy operates three NADEPs, located at Naval Air Station North Island, CA, Naval Air Station Jacksonville, FL and at the Marine Corps Air Station, Cherry Point, NC.

4. Advanced Traceability and Control Program

In an effort to simplify the DLR retrograde process, the Advanced Traceability and Control (ATAC) program was established in 1986 as the Navy's first logistics pipeline to couple logistics and transportation into a single physical distribution system. ATAC is specifically designed to provide traceability, accountability, and visibility for each DLR within the repair pipeline (NAVSUPINST 4421.20, 1999). The ATAC is comprised of three major elements: the nodes, the hubs, and the ATAC system database (DoD Inspector General, 1996).

Under the ATAC system, Navy fleet units return DLRs to the supply system through one of twelve nodes located throughout the world or directly to one of the two hubs, located at Norfolk, VA and San Diego, CA. When the DLR reaches a node or a hub, the returned DLR is registered in the ATAC database with a unique document number. At the hubs, the ATAC contractor records the DLR receipt in the ATAC database and the DLRs are screened to verify that the correct national stock number is indicated on the turn-in document. Information in the ATAC database is used by NAVICP to determine the disposition of each DLR that is returned by end users for repair.

The ATAC system network significantly reduces the fleet unit workload because the ATAC system handles nearly all DLR returns. In addition, fleet units send essentially all failed components to one place. Individual shipping and disposition decisions are left to ATAC system personnel. This system has allowed the Navy to achieve efficient shipment consolidations and better response times without incurring increased transportation costs (DoD Inspector General, 1996).

B. NAVAL AVIATION MAINTENANCE LEVELS

Each Naval repairable item is classified as either Field Level Repairable (FLR) or a Depot Level Repairable (DLR). This classification determines the maintenance level that performs repairs or condemns unserviceable items. A component identified as a FLR is repaired or condemned at the Organizational level or the Intermediate maintenance level in accordance with the Master Repairable Item List (MRIL) and the applicable maintenance code.

Maintenance codes are used to determine which maintenance level qualifies for removal and replacement of an unserviceable component. This maintenance level determination is based both on engineering assessments during the design phase of the equipment and continuing evaluations of the maintenance skills and capabilities at the three levels of maintenance.

The maintenance code appears on a spare parts record known as the Allowance Parts List (APL). The APL is unique to each Naval military system and is available to both the supply and maintenance personnel. The first position of the code identifies the lowest echelon authorized to remove and replace the component. The second position of the code identifies the activity authorized to perform the maintenance on the removed component (NAVSUP P-485, 1999).

The Navy has developed a three-tiered Naval aviation maintenance system. The type of maintenance performed at the different levels is based on the skill level of the maintenance personnel and the capability of the facilities. The three levels of maintenance are organizational (O-Level), intermediate (I-Level) and depot (D-Level).

1. Organizational Level Maintenance

Maintenance personnel within the aircraft squadrons, perform organizational level maintenance on FLRs. O-Level maintenance is involved primarily with the day-to-day operation of their respective aircraft rather than in-depth maintenance. The maintenance performed at this level is preventive in nature, and includes visual inspections, periodic performance evaluations, cleaning, adjusting, removal and replacement of components. Generally, removed components are forwarded to either the I-Level or D-Level for repair.

2. Intermediate Level Maintenance

Intermediate level maintenance for FLR aviation components is performed by Aviation Intermediate Maintenance Departments (AIMDs), which normally specialize in a specific model or series of aircraft. I-Level maintenance facilities are located both at sea on aircraft carriers, on large amphibious ships, and ashore at Naval air stations. The maintenance personnel in these facilities remove defective components, replace components, effect repairs, and return the component to the local supply department as a Ready For Issue (RFI) item. The AIMDs are better-equipped and staffed to effect repairs than O-Level organizations. The mission of these I-Level organizations is to provide on-site expeditious repair of components to facilitate operational readiness and maximize sortie generation and sustainability for deployed units (Cruz, 1997).

3. Depot Level Maintenance

Depot Level maintenance is performed at Designated Overhaul Points (DOPs) or depots, which are the most advanced maintenance organizations available to effect component repairs. DOPs have better-equipped facilities and artisans with advanced maintenance skills, to effect repairs that I-Level organizations are not equipped or trained

to complete. DOPs have the capability to completely rebuild, overhaul and calibrate complex equipment. Repairs at the D-Level are the focus of this thesis.

C. COMPONENT CLASSIFICATION

There are three categories of wholesale parts in the Naval Supply System: equipage items, repairable items and consumable items. Equipage items are generally non-installed durable items, which are located in operating spaces or other designated locations. An example of equipage is circuit boards stowed in the same space as the equipment to test specific gear upon failure. Repairable item components are parts that can be repaired economically when they become unserviceable. Consumable items are classified as parts that are neither equipage nor repairable.

The Material Control Code (MCC), which is available from the Federal Logistics Catalog (FEDLOG), determines the component classification of each item. A Material Control Code of D, for example, identifies a component as a Field Level Repairable. A Material Control Code of E, G, H, Q or X identifies a component as a Depot Level Repairable.

D. SUPPLY CONDITION CODES

Supply condition codes are used to determine readiness for issue and use. There are currently 17 condition codes that the Naval Supply System uses, ranging from issuable to scrap. In this thesis, the following four condition codes will be considered:

1. A-Condition: New, used, or reconditioned materiel that is serviceable and issueable to all customers without limitation or restriction. Includes materiel with more than six months of shelf life remaining.

2. F-Condition: Economically repairable materiel that requires repair, overhaul, or reconditioning.

3. G-Condition: Materiel awaiting additional parts or components to complete the end item prior to issue, generally while in D-Level maintenance.

4. M-Condition: Materiel identified on an inventory control record but which has been turned over to a maintenance facility or contractor for processing.

Each condition code determines the actions of the organizations involved in the repair process. The available quantities of A-condition components directly influence a fleet organization's ability to effect repairs. If DLRs are stocked at the squadron level and the maintenance code specifies O-Level, the equipment can be repaired. The primary influences are the stocking levels and maintenance codes. The actions of the ATAC program, the Designated Overhaul Point (DOP) and the Designated Support Point (DSP) are not influenced by the quantity of components in A-condition. NAVICP-P is responsible for the management of materiel under its cognizance. The quantity of components in A-condition determines repair induction scheduling, component acquisition scheduling, and geographical stocking location. Only A-condition materiel can be counted as inventory available for issue.

The quantity of F-condition components directly impacts DOP scheduling and induction processes. The F-condition components in the Naval Supply System are the principal components of the ATAC program. The ATAC nodes are responsible for managing failed components, and for transferring them to an ATAC hub and subsequently to the applicable DOP. The DOP workload is directly influenced by the available quantity of F-condition components. The quantity of F-condition components ready for induction into the repair process is also an indicator of the quantity of parts and

materiel that must be available to affect their repairs. NAVICP-P views the number of F-condition components as the quantity available for induction into the depot repair process.

E. NAVAL AVIATION DEPOT PROCESSES

The determination of D-level industrial workload is based on the requirements of the operating forces as established by the Chief of Naval Operations (OPNAVINST 4790.2G, 1998). The CNO determines aircraft requirements based on a model prediction and any known special requirements. The model statistically ages the aircraft inventory by applying deferral rate data, attrition, and pipeline data resulting in a projected rework induction profile. These requirements for aircraft, power plants, missiles, components, support equipment, and support services are programmed by Commander, Naval Air Systems Command (NAVAIR) and assigned for rework at the various Naval, interservice, or commercial contractor aviation industrial establishments.

The NADEP integrates the efforts of many entities within the Depot Repair Cycle. Figure 2.2 illustrates the elements involved with bringing a failed DLR item from F-condition to A-condition.

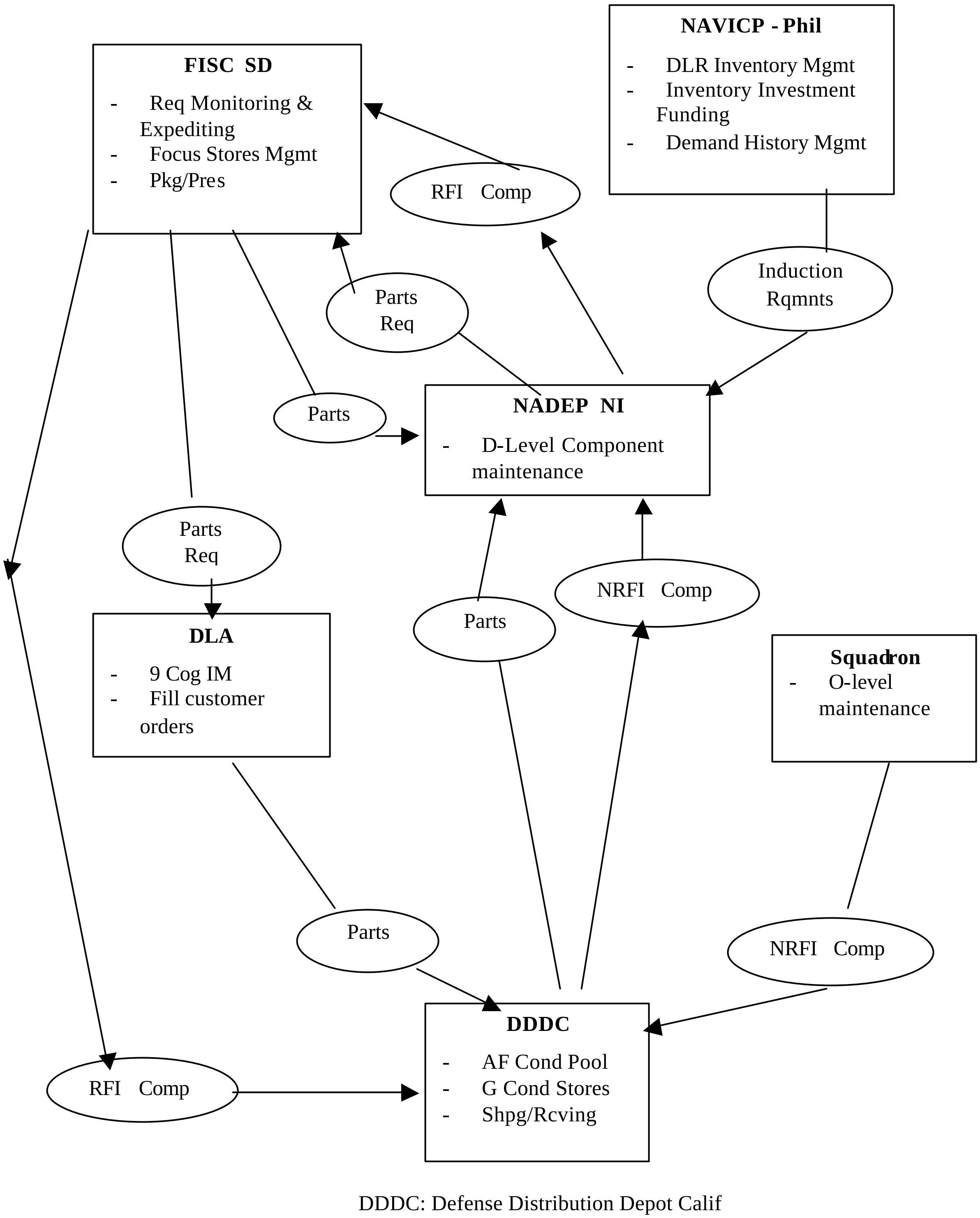


Figure 2.2 NADEP NI Component Repair Process Flow

NAVAIR (AIR-6.0) manages the Naval Aviation Depots (NADEPs) and is responsible for scheduling the depot-level workload. Industrial workload is scheduled on a quarterly basis by NAVAIR for the NADEPs. These quarterly rework schedules, along with associated man-hour allocations, funding controls, and manpower targets are updated at fleet readiness support meetings, chaired by NAVAIR and attended by representatives from each of the NADEPs and from NAVICP. At these meetings, representatives review the quarterly schedules of assigned rework to ensure that the man-hours available are sufficient to meet the scheduled requirements. When needed, interim meetings may be called in the event that workload contingencies occur or changes are required between the scheduled quarterly meetings.

The Component Program encompasses work performed primarily on uninstalled or removed aeronautical components, systems, equipment, and training devices which have been designated as DLRs by NAVICP. Component rework is a process that involves testing, checks, and rework to return F-condition materiel to A-condition. Navy requirements for repairable components are developed by NAVICP. These requirements are generally based upon comparison of the total stocks required to the quantities of serviceable items on hand and scheduled for receipt in the near future. This requirement determination is known as the stratification process.

For workload purposes, the rework of components is allocated man-hours of work at each NADEP. The scheduling of components is a demand operation based on the immediate needs of the operating forces and is a coordinated function between NAVICP, the operating forces and NAVAIR (AIR-6.0D). The scheduling of components for rework is accomplished through the following programs and systems.

1. The application operation, B08, provides a schedule based on demand. B08 is a UICP Repairable Management Program that has four major functions: Repair Requirements Scheduling, Not Ready for Issue (NRFI) redistribution, DOP Workload forecasting and Component Rework forecasting (NAVICPINST 4000.33, 2000). NAVICP issues a weekly B08 to each NADEP with the following scheduling information:

    - Level I. Not Mission Capable Supply (NMCS) and Partially Mission Capable Supply (PMCS) in addition to special expedite selected project candidate/priorities 01 backorders.
    - Level II. All other end use back orders and funded planned requirements.
    - Level III. Stock Back Orders: planned requirements due within rework turnaround time (TAT) or a demand is expected during the rework TAT.
    - Level IV. Planned requirements due within the rework TAT plus 30 days demand forecast.

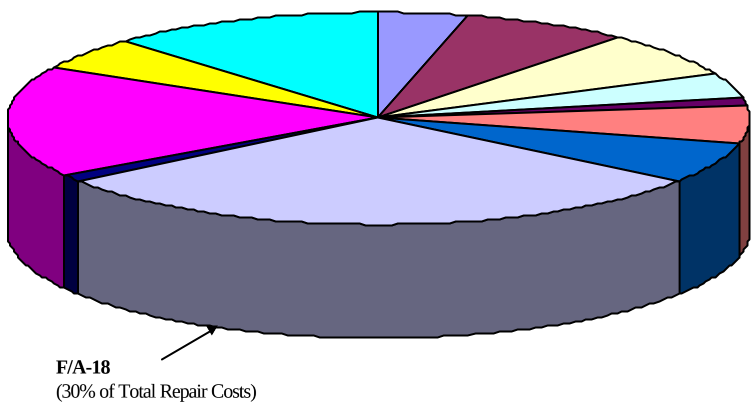
2. Under the "Level Schedule Repair Program," repairable components exhibiting high demand and high dollar value are scheduled by means of periodic joint meetings, which determine committed production schedules. These meetings, hosted by NAVICP, include representatives from each of the major aviation commands and the various supporting supply activities. Repair requirements for these items are projected over a five-quarter horizon; actual schedules are based on an average quarterly requirement. This scheduling technique facilitates a smoother flow of units and allows the rework facility to make optimum, economical use of available industrial resources.

3. Emergent requirements are met through a program known as "Customer Service." Unplanned B08 and schedule increases are met by increasing either the artisan work force or artisan work hours (Fuller, 2000).

The NADEP has demonstrated the capacity to induct an increasing quantity of F -condition materiel to meet the unplanned B08 requirements. By exercising a flexible workforce structure, NADEP managers can employ short-term contracted artisans to meet demand fluctuations (Fuller, 2000). This flexibility increases customer service and also ensures that a program, such as Carcass Express, will not unduly stress the NADEP capacity. All DLRs considered in this thesis are sent to NADEP, North Island, CA. The component repair workload program at NADEP, North Island had a component repair budget of $219.5 million in fiscal year 2001. NAVICP was the largest customer, representing 85 percent ($188.3 million) of the NADEP workload. Figure 2.3 illustrates the large financial and managerial impact that F/A-18 repairs have on NADEP workload.

The Defense Logistics Agency (DLA) manages the subcomponents required to effect DLR repairs. These subcomponents, generally 9-COG materiel, have a significant impact on the speed with which repairs can be made. NADEP and DLA have undertaken a joint effort to reduce the delay in the repair cycle due to awaiting subcomponents from DLA. In the nine-quarter period from October 1998 to December 2000, the lack of carcasses has represented the primary constraint to increasing the rate of component repair. The 9-COG DLA materiel, which formerly represented the largest constraint to component repair, is now the second most limiting factor to constraining component repairs. Currently, the added time delay for unavailable 9-COG materiel is approximately five to eight days of RTAT (Fuller, 2000).

Component Workload by Application
FY-01
Workload Base $219,462,394



Component Workload by Application
FY-01
Workload Base 1,142,616 MHRS

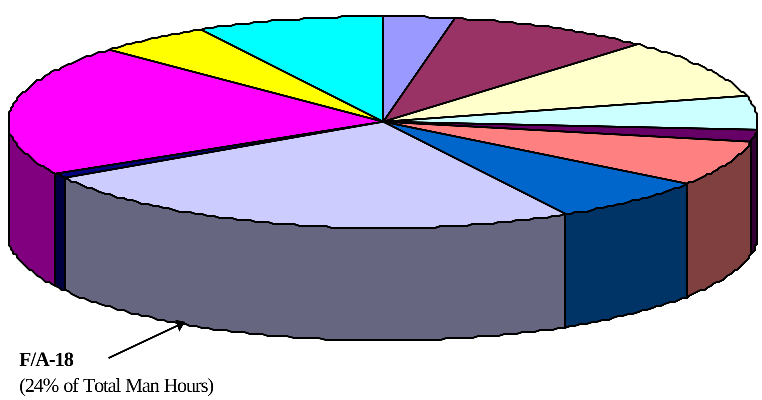


Figure 2.3 NADEP NI Workload Base by Airframe

Each area of the graph represents a system repaired by NADEP NI. The largest portion of the NADEP NI Components Program support is provided to the F/A-18. In terms of funding and man-hours, the F/A-18 represents the largest repair commitment of any airframe repaired by NADEP NI (From Fuller, 2000).

F. NAVAL TRANSPORTATION COMMAND (NAVTRANS)

The retrograde segment of the Depot Repair Cycle can be defined by data collected by NAVTRANS. The NAVTRANS Operations Department has four main components. Each component performs coordinated transportation services for fleet customers and transportation operations. The services include cargo and traffic routing management, shipment diversion, expediting high-priority cargo, and forecasting air and surface transportation for the Navy. In addition, NAVTRANS provides contractor oversight of the shipping, transportation and receiving for Navy DLRs and return or storage of the repaired materiel. NAVTRANS is the key player in the development and testing of new ATAC system programs designed to resolve shipping and receipt discrepancies on ATAC DLRs moving to commercial or government sites.

G. THE INFLUENCE OF THE REPAIR CYCLE ON INVENTORY

The Navy's consumable inventory model was designed to conform to the requirements of DoD Instruction 4140.39 (July 1970). However, there is no such guidance for the procurement or repair of DLRs. Each service has developed a unique inventory model. The objective of the Navy inventory model is to determine for each item, how much to buy, when to buy, how much to repair, and when to repair so that average annual total variable costs are minimized (Maher, 1993). The Navy's DLR model is based on the consumable model, but with significant differences. First, UICP views the DLR system as two separate systems in the modeling process: one for procurement of new materiel and the other for repair of F-condition DLRs. Second, when a certain attrition level is reached, procurement must be initiated to replace the lost

units. The lead-time attrition demand for the procurement is assumed to be composed of a weighted average of lead-time and the quarterly demand rate (Maher, 1993).

H. THE CARCASS EXPRESS PROGRAM

This thesis demonstrates that by returning DLR items in F-condition directly to the NADEP, thus decreasing the transportation leg of the repair cycle, there is less variability in the quantity of repaired DLR items. Reduction in transportation time will allow NAVICP to determine more accurately the number of purchases required to effectively meet quarterly demand over extended periods of time. By evaluating the components of the depot repair cycle and determining the effect of timesavings on an element of that system, the inventory required to meet demand levels can be more closely determined. This will allow NAVICP to determine with more certainty when specific DLR parts will be available for inventory and the quantity that will be available to meet quarterly demand.

Similar to the express program for the S-3 airframe repairables, the Carcass Express program has been implemented in an effort to shorten return times for critical DLR parts associated with the F/A-18 (Archer, 2000). The amount of inventory currently available is insufficient to meet regular demands for this airframe. In addition, insufficient DLR parts in F-condition (carcasses) are available for induction into the repair process. This has created a carcass constrained repair pipeline. In an effort to make more assets available, Carcass Express is designed to reduce the time between turn-in and repair induction for specific DLR parts identified by NAVICP. NAVICP has established the following criteria to determine which DLRs are in critically short supply in the F/A-18 supply system (Mueck, 2001):

1. *Carcass constrained* items. Insufficient carcasses to induct into the maintenance system for repair in order to meet current demand levels.

2. Significant quantity of *backorders*. Backorders represent DLRs that have insufficient ready for issue quantities to meet current demand levels. A buffer of DLR carcasses does not exist to effect repairs and provide initiation into inventory.

3. A possible tangible benefit to be gained by *introducing more* carcasses into the repair pipeline sooner.

4. DLR items that exhibit a high scrap or wearout rate.

5. DLR items that have a weight limit of 70 pounds or less.

In 1999, approximately 66 percent of the aviation supply budget supports repair (Gruber, 2000). The remaining 33 percent was utilized to buy spares to meet anticipated quarterly demand. The current Carcass Express list contains approximately 1,200 NIINs and constitutes approximately 5 percent of the total ATAC volume. Each DLR item on the Carcass Express list is uniquely identified on the MRIL. The MRIL indicates the special delivery requirements placed on the set of NIINs identified as Carcass Express items. Carcass Express was established specifically for the F/A-18 C/D because of the large percentage of maintenance work represented within the organic repair network.

III. DATA USED IN THE ANALYSIS

The data utilized for research were generated from the key components of Naval Aviation: NAVICP-P, Naval Transportation Command (NAVTRANS), and the NADEPS, which comprise the maintenance arm of NAVAIR. These components are closely linked together and support overall aviation readiness. The data used to model the Depot Repair Cycle were obtained from databases in use throughout the organizations mentioned above. The analyses focused on the DLR items identified by NAVICP as discussed in chapter II. The list of National Item Identification Numbers (NIINs) identified on the Carcass Express list by NAVICP established the baseline DLRs to examine the Depot Repair Cycle segments.

A. NAVTRANS DATA

Data provided by NAVTRANS are used by NAVICP to determine shipping times of DLRs turned in for repair. When a DLR is reported to have failed, it is assigned F-condition. When the status of the DLR changes, a recorded entry is developed in the repair cycle that is entered into the NAVICP computer. It is the responsibility of NAVTRANS to collect these data and present them in a format that is conducive to analysis by UICP (Barraco, 2001). The NAVTRANS data considered in this thesis are for fiscal year 1998.

The fiscal year (FY) 1998 NAVTRANS data give an overview of the ATAC system. Table C.1 of Appendix C describes the NAVTRANS data fields that were used in the analysis. Each record provides the time that a DLR fails, known as the document date, and the time the DLR is turned into the hub for transfer into the repair pipeline. The

elapsed time between these two dates gives the time required for a DLR to travel from the point of origin to the repair facility. This is referred to as the "transportation time" in the model.

The FY1998 NAVTRANS database contains 8,610 records, each pertaining to an individual repair transaction. However, it was found that 773 of these records (9.0 %) had document dates that were the same as, or later than, the hub receipt dates. These errors may be introduced because remote ship locations can delay the recording of a document date under some circumstances (e.g., port visit, or return from deployment). Operational constraints can affect transportation time and introduce delays that may not be captured in the NAVTRANS data. The 773 records with date problems were excluded from the analysis.

B. RTAT DATA

The repair turnaround time (RTAT) segment of the Depot Repair Cycle is defined by the procedures of NADEP. RTAT data spanning the first quarter of 1996 to the last quarter of 1999 contain 33,607 records pertaining to the 185 DLRs that identify when a repair transaction was completed and the length of time (days) needed to complete the repair. When a DLR item is inducted into the NADEP, the "RTAT clock" is initialized. When the DLR item is repaired and designated as A-condition, the RTAT clock stops. RTAT quantifies the time required to effect repairs to a given DLR component.

The RTAT data do not capture each aspect of the repair process. Delay is introduced when parts are unavailable to complete repairs. The affected DLR item is then designated G-condition, i.e., awaiting parts, until the subcomponents are available. NAVICP and NADEP differ in how this time awaiting parts impacts RTAT. NAVICP

uses the total time to complete a repair, which causes RTAT to be inflated. However, NADEP suspends the RTAT clock when an item is designated G-condition. This causes some discrepancy when the two organizations compare results of the repair process.

C. UICP FORECAST DEMAND DATA

The UICP system utilizes data stored and maintained in interrelated files, which must be kept in agreement with one another (Navy Aviation Supply Office, 1991). The UICP model provides quarterly forecast demand quantities for each DLR item. For the purpose of analysis, the forecast demand was retrieved for a period beginning with the first quarter of 1996 and ending the first quarter of 2000. The forecast demand data was collated to view trends and conduct analysis over a period of four years from fiscal years 1996 to 1999. In addition to demand data the wear out rate or scrap rate was retrieved. The wear out rate associated with any given part will create a continuous procurement deficit over the lifespan of the DLR unless purchases of new DLRs can be done at the right time and for the correct quantity. This emphasizes the importance of predicting the quantity of inventory available through repair. As with any contract purchase, procurement lead times play a major role as to when newly purchased inventory is actually available to meet current demand levels.

Chapter IV examines the effect that reducing the Depot Repair Cycle time has on Naval inventory. Introducing carcasses into the repair queue faster increases the chance that scheduled maintenance repairs are performed in a timely manner. Building a queue with less variability will create a stable pool of carcasses available to the depot when scheduling quarterly repairs. Managing the uncertainty with which carcasses enter the

queue more effectively on a quarterly basis allows the maintenance manager to effect repairs in a more efficient manner over time.

IV. DEPOT REPAIR CYCLE INVENTORY AVAILABLE MODEL ANALYSIS

In this chapter, the effect of the Carcass Express program on inventory levels is examined. A simulation model is created to quantify inventory levels that result from the decreased transportation times for the DLRs in the Carcass Express program. Before presenting the results of the analysis, the research and methodology that was used is described.

A. SELECTION OF DLR ITEMS FOR ANALYSIS

The initial segregation of the data provided by the sources discussed in Chapter III, identified a unique set of DLRs associated with the Carcass Express NIINs. From the initial 1,200 NIINs, comparing the Carcass Express NIINs with the NIINs represented in the RTAT data set reduced the initial RTAT data sets. Using the DLRs that had records in each data set over the period 1996-2000, a list of 988 NIINs with 42,117 observations was identified.

The transportation data, which represents the time between part failure (document date) and delivery to the repair facility (hub receipt date) for all DLR items moved during 1998, was reduced to DLR items that applied only to the Carcass Express NIINs. The UICP data provided by NAVICP was similarly reduced to include only the DLR parts contained in the Carcass Express group.

Isolating NIINs that were represented in each of the available data sets allowed for the analysis of the common data points for each segment of the Depot Repair Cycle. Comparing NIINs that appear in each quarter (1996 to 1999) of the forecast demand data

and each of the RTAT data frames reduced the number of NIINs common to all portions of the Depot Repair Cycle to 185. The 185 DLR items are identified in Appendix B. The NIINs were further segregated into components consisting of circuit card assemblies, electrical components, and mechanical components. This allowed DLR items with similar repair characteristics to be evaluated throughout the analysis. The 185 DLR items represent a total replacement cost of approximately $900 million from 1996 to 1999.

Table 4.1 illustrates the data set reductions that resulted from restricting analyses to the 185 DLR items.

Table 4.1 Reduction of Data Sets to 185 DLR Items

Database	Initial size (records)	Reduced size (records)
RTAT	733,136	33,607
NAVTRANS	419,385	7,835
UICP Demand	91,946	5,955

Figure 4.1 shows a histogram of the UICP forecast demand (First Quarter 2000) for the 185 DLR items used in the analysis. The histogram shows that a majority of the DLR items have a relatively small quarterly demand, but a small number of items have relatively large demand.

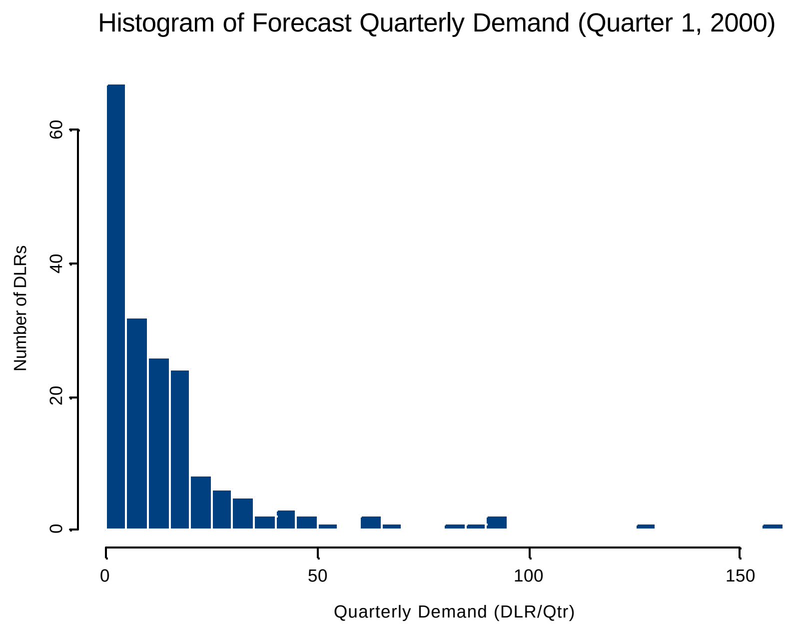


Figure 4.1 Quarterly UICP Forecast Demand Histogram

The histogram has a sample size of 185 DLR items. The forecast demand ranges from 0.46 to 158.01 DLR items per quarter. The average forecast demand for quarter 1 of FY2000 is 15.37 DLR items per quarter.

The NIINs were divided into two categories based on their median transportation times. The transportation time was determined from the following formula:

Transportation Time = Hub Receipt Date – Document Date

The Carcass Express program will achieve a specific reduction in the length of transportation time required to deliver a DLR item to the depot. By bypassing the hub, the time required to ship DLR items from the receiving entity (hub) to the repair facility (NADEP) will be eliminated. This represents a savings of approximately three to five days, on average. The NAVTRANS data used in the analysis showed actual shipping time from the hub to the depot ranging from zero to 973 days.

A histogram of median transportation times for the 185 DLRs considered in the analysis is shown in Figure 4.2.

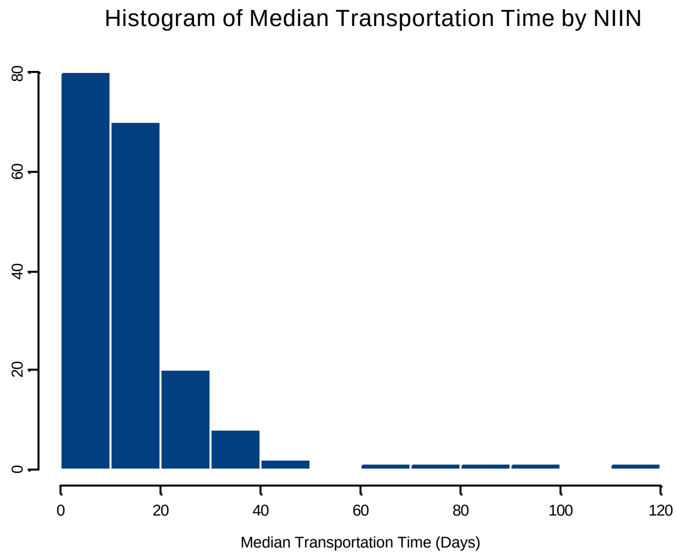


Figure 4.2 Median Transportation Time Histogram

Figure 4.2 combines each of the 185 NIINs for analysis. Each NIIN contributed one data point in the histogram. The median transportation times were derived from 419,385 observations in the FY1998 NAVTRANS transportation data.

Most of the DLRs had median transportation times less than or equal to 20 days. For the purpose of analysis, the DLRs were split into two groups: median transportation times greater than 20 days (High Group), and those with median transportation times less than or equal to 20 days (Low Group). The histograms shown in Figure 4.3 provide a graphical illustration of the two groups of median transportation times. All transportation times are developed from FY1998 NAVTRANS data.

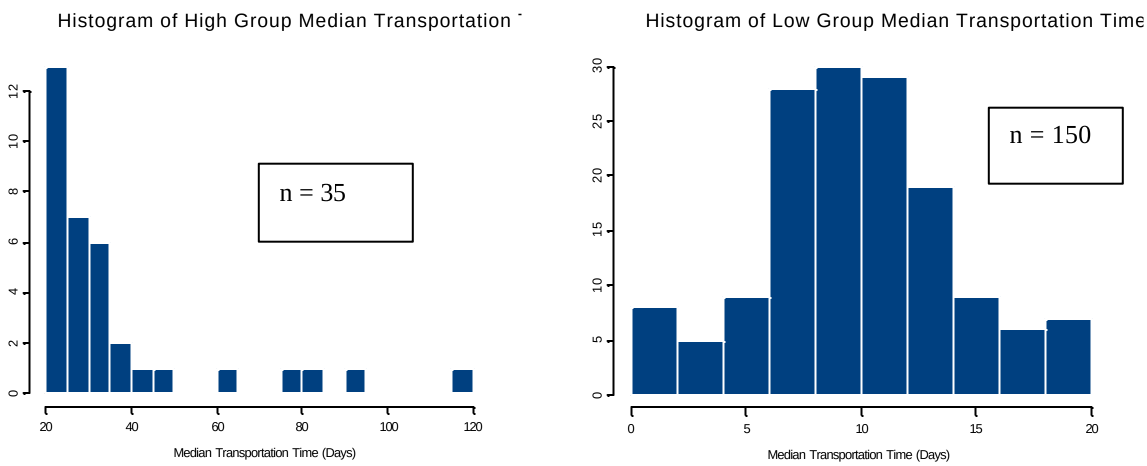


Figure 4.3 High Group and Low Group Median Transportation Times

The High and Low Groups consist of 35 and 150 DLRs, respectively. A description of the DLRs represented in each group is provided in Appendix B.

Figures 4.4 and 4.5 illustrate the amount of inventory available by quarter for each of the NIINs represented in both the High and Low Groups. Figure 4.5 shows only the top 35 of the 150 Low Group NIINs for ease of comparison.

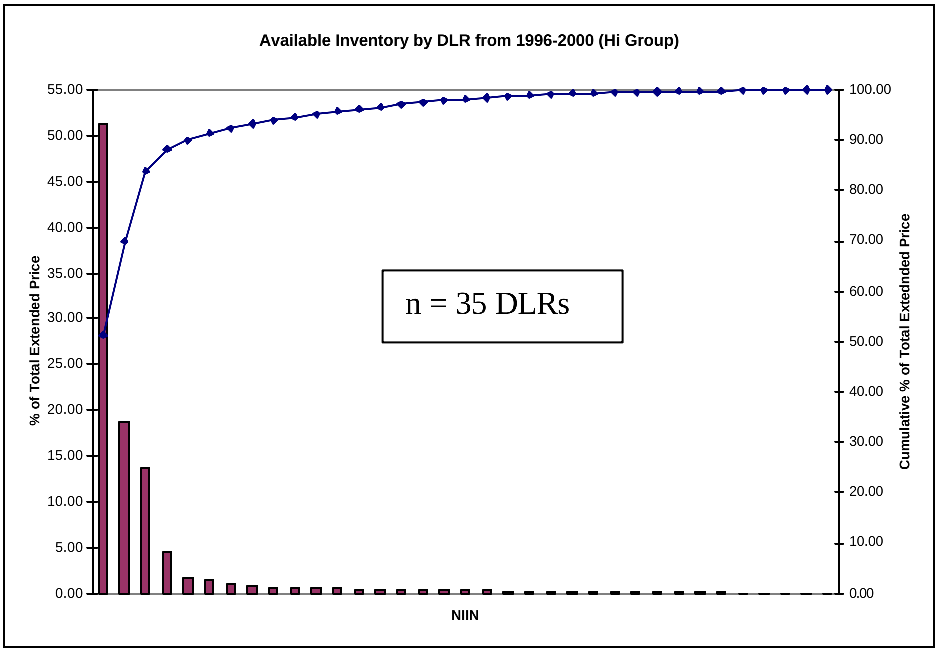


Figure 4.4 Pareto Diagram of Inventory Available for the High Group

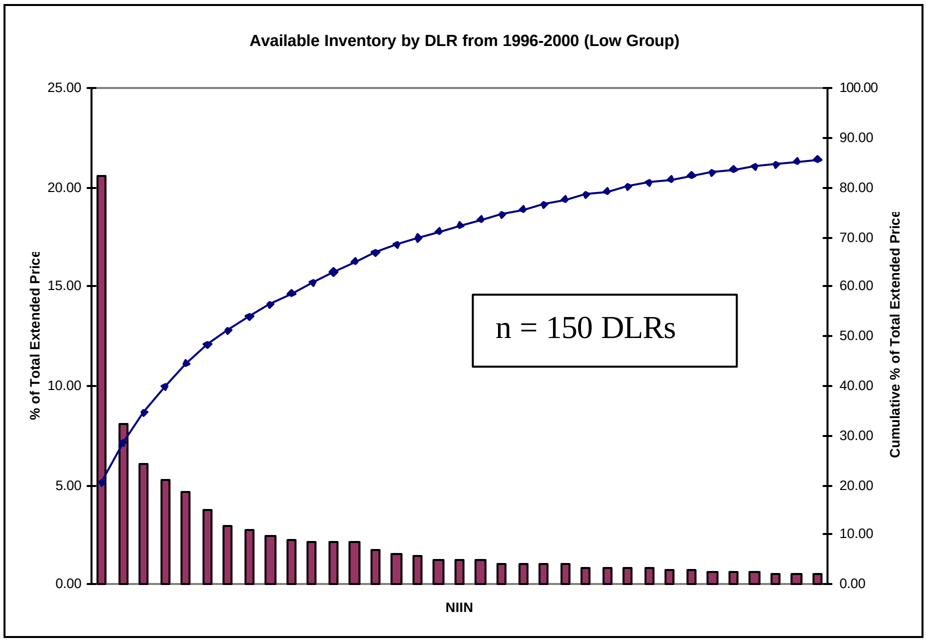


Figure 4.5 Pareto Diagram of Inventory Available for the Low Group

Available inventory represents the amount of inventory generated from the depot repair cycle. The extended price for each NIIN in the High and Low Groups represents the quantity of DLRs generated from repair at the standard price. *Columns* represent the percentage of total inventory at extended price by NIIN. *Dashed lines* show the cumulative percentage of inventory at extended price added by each additional NIIN.

These figures illustrate that a majority of the value of inventory is represented in only a few of the NIINs within both groups. For example, NIIN 012328815 represented 51 percent of the value of inventory in the High Group, and NIIN 01353373 represented 21 percent of the value of inventory in the Low Group. It should be noted that these DLR items do not necessarily represent the NIINs with the highest price or greatest shortage in each quarter.

The elements of the transportation time data are defined in Appendix C. A major assumption was that it was valid to apply results from the 1998 data across the four-year time frame 1996 through 1999. The FY1998 data had the smallest entry error rate of any data set maintained by NAVTRANS (Barraco, 2001).

Many of the DLRs represented in the Depot Repair Cycle pipeline were generated in shipboard squadrons. It is not uncommon for a shipboard supply department to delay a F-condition DLR item shipment due to deployment or other constraints. This may explain some of the longer transportation times associated with the DLR items used in the analysis. Because this is common in any given year, the DLR transportation times will exhibit similar Depot Repair Cycle time characteristics.

B. COMPUTING RTAT AND THE AVAILABLE INVENTORY

The RTAT database, which is also described in appendix C, provided information on when a particular DLR item repair had been completed (COMPDT) and the turnaround time (TAT) associated with each repair. The following formula was used to compute the date each DLR entered the Depot Repair Cycle:

Entry Date = Completion Date (COMPDT) – Turnaround Time (TAT)

Repairs that were completed in a given quarter were counted as available for inventory at the beginning of the next quarter. The data collected spanned the timeframe of 1996 through 1999. Available inventory generated from repair did not become available until the second quarter of 1996. No inventory levels were computed in the first quarter of 1996. In order to capture inventory that was available from the last quarter of 1999, the first quarter of 2000 was treated as the final quarter of observation. This defines a period of sixteen quarters over which inventory levels can be studied.

C. QUARTERLY DEMANDS

Two types of demand were used for comparison in the analysis; UICP forecast demand and the demand registered when a DLR item fails, defined as direct demand.

1. **Forecast demand** is the UICP model forecast of the quantity demanded for an item in a particular quarter. Forecast demand is an estimate of expected demand based on data that are observed over an extended period of time. Forecast demand is continuous, meaning quarterly values can be fractional. Forecast demand attempts to predict the future, and is not linked to specific repair transactions.

2. **Direct demand** is the demand generated when a DLR item fails in the squadron and enters the repair system. Direct demand can only occur in discrete quantities. Unlike forecast demand, direct demand is linked to the repair cycle. However, direct demand fails to capture all sources of demand, for example, demands that arise from the failure of a component that is classified as beyond repair capability.

Forecast demand fails to capture the full benefit of the Carcass Express program, because it is not based on a direct connection between supply and demand for individual DLR

item. By simulating the transportation component of the repair cycle and identifying a demand with each DLR failure, the repair cycle can be evaluated to determine the amount of inventory available, item by item, to meet required demands. This will generate a better comparison to determine exactly how much demand can be met by inventory available directly from NADEP repairs. Figure 4.6 illustrates the difference between the UCIP forecast demand and the direct demand.

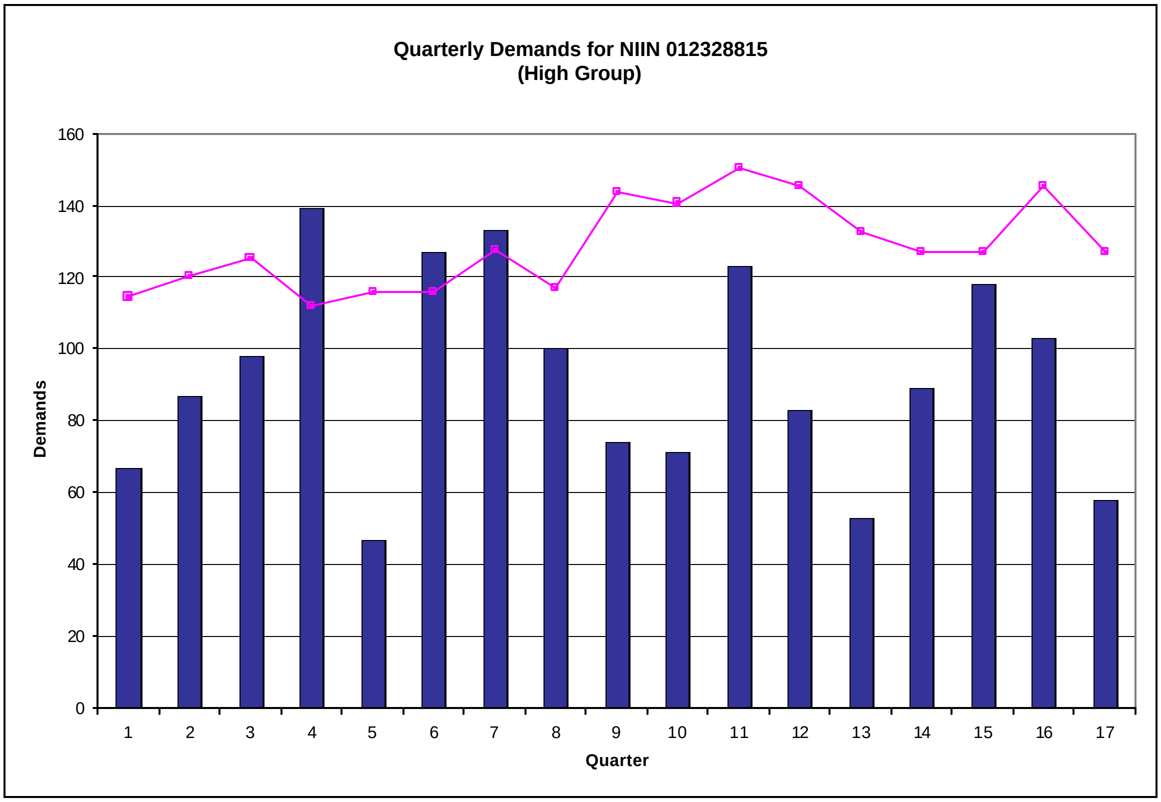


Figure 4.6 Direct Demands vs. UICP Forecast Demands

The line represents the UICP Forecast Demand. The columns represent the Direct Demand. Direct Demand represents the demand generated when a DLR item fails in the squadron. Direct demand will generally lag UICP demand because wearout rates are not considered. Direct Demand constitutes 71.8% of UICP Forecasted Demand from 1996 to 2000.

Figure 4.6 illustrates the smoothing effect of the UICP model. UICP forecast demand is generally greater than direct demand because it encompasses all sources of demand, including demand that is not connected to the repair cycle.

D. SIMULATION ANALYSIS

Knowing the quarterly demands for each of the DLR items considered in the analysis, a simulation was run to determine the quantity of inventory available by quarter after implementing the Carcass Express program. Quarterly simulated available inventory is directly compared to the actual available inventory, which resulted from using the original shipment procedures. The same amount of inventory ultimately becomes available with or without the Carcass Express program, but at different times over the 16 quarter cycle.

A simulation was designed using the bootstrap method to randomly sample, with replacement, from the High and Low Group transportation times during each run. The transportation times of all DLRs in each of the two groups were pooled, and bootstrap samples were applied to each item individually within groups. Each random sample constituted a transportation time to apply to the Depot Repair Cycle Time in order to determine when inventory became available over the four-year duration. The available inventory for each quarter was accumulated over the replications and an average available inventory was determined by dividing by the number of replications. Simulated repair completion dates were calculated as follows:

X = Original Completion Date – (29/39) ´ Simulated Transportation Time

Simulated Completion Date = max(X, Original Completion Date + 5)

In other words, a simulated RTAT of less than five days was set equal to five days in order to maintain a more realistic repair cycle model. The simulation was run 1,000 times using the software package S-Plus. Following each iteration, a new inventory level was calculated to quantify the effects of the Carcass Express program.

Once the simulated available inventory was generated, a comparison of the percentages of demand met by this inventory was determined. The next section presents these comparisons and illustrates the amount of procurement required to meet the deficit between repair and demand.

E. RESULTS OF THE ANALYSIS

Figures 4.7 and 4.8 illustrate how the observed and simulated available inventory through the repair cycle varied quarter by quarter throughout the four-year period for a NIIN from the High and Low Groups. The specific NIINs were chosen because they represented the greatest inventory impact within their respective groups. The ability to meet quarterly demands is directly related to inventory availability. Figures 4.7 and 4.8 compare the available inventory through the original repair system with the Carcass Express initiative. The shorter depot repair cycle time created through simulation actually produces a smoother inventory curve over the course of sixteen quarters.

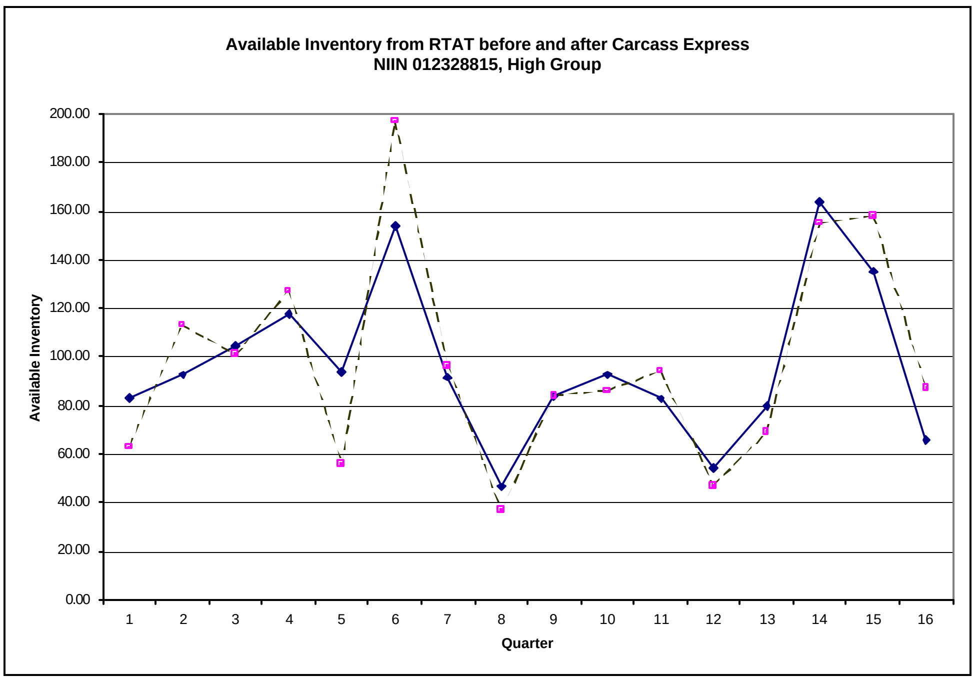


Figure 4.7 Simulated and Actual Inventory Comparison (High Group)

In Figures 4.7 and 4.8, the *dashed line* represents original inventory available from RTAT over the four-year period. The *solid line* shows the inventory available when Carcass Express is introduced. The 16 quarters split the four-year period evenly with the second quarter beginning April 1996 and the last quarter beginning January 2000. Inventory that is repaired during a given quarter is assumed to be available for issue the following quarter.

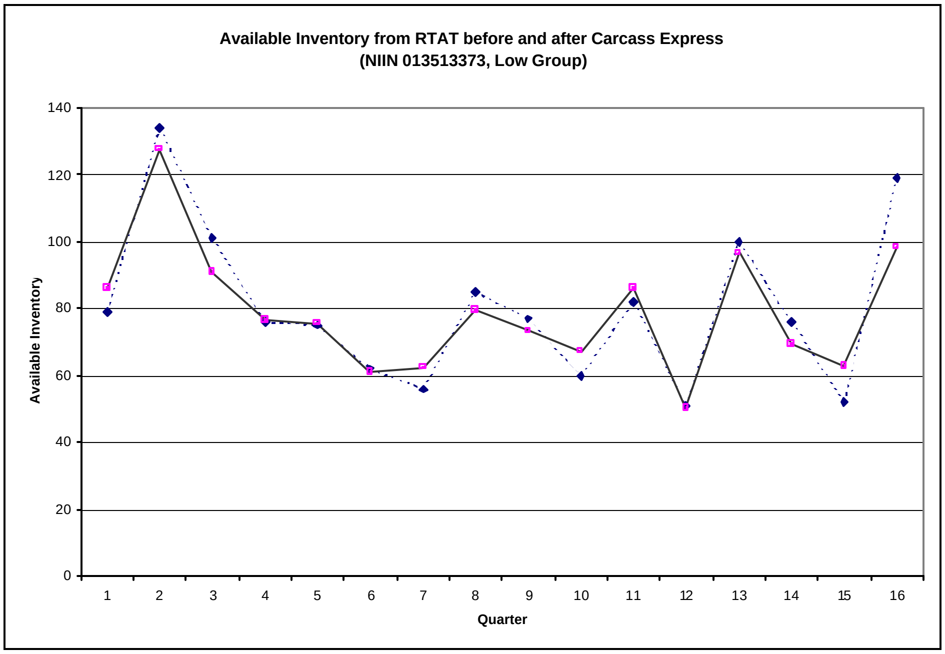


Figure 4.8 Simulated and Actual Inventory Comparison (Low Group)

To evaluate if the inventory smoothing effect was a valid conclusion, a series of hypothesis tests were conducted. For a fixed NIIN, a hypothesis test compared the between-quarter standard deviations averaged over all simulations with the between-quarter standard deviations calculated from the RTAT data (SD_o). Let μ_{SD} denote the expected value of the between-quarter standard deviations under the assumptions of the simulation model. The null and alternative hypothesis are described as follows:

H_o: $\mu_{SD} = SD_o$
H_a: $\mu_{SD} < SD_o$

The hypothesis tests are conducted using the average of the simulation standard deviations and their estimated standard errors, based on n = 1000 simulations. The null hypothesis is rejected at the α = .05 level if the corresponding z-statistic is less than

-1.645. For the High and Low groups respectively, the null hypothesis is rejected at the $\alpha = .05$ level, for 80 percent (28 of 35) and 77 percent (115/150) of the items.

The overall reduction in variability is illustrated in Table 4.2. Specific standard deviation reductions for the two isolated NIINs are provided in Tables 4.3 and 4.4.

Table 4.2 Weighted Mean Reduction of Inventory from Repair

Transportation Group	Standard Deviation Percentage Reduction
DLRs with Median Transportation time greater than 20 Days	20 %
DLRs with Median Transportation time less than or equal to 20 Days	9 %

The percent reduction is an item-by-item reduction using the weighted average, by DLR item standard price, of the Standard Deviation for the inventory available from the repair process. This calculation was done for the High and Low Groups over the period 1996 – 1999.

Table 4.3 High Group Available Inventory Example

NIIN 012328815	Mean Available Inventory (DLR items/QTR)	Standard Deviation (DLR items/QTR)
Without Carcass Express	92.35	43.48
With Carcass Express	90.60	32.54
Average of the Simulation Standard Deviations (SDs)		32.95 (SE = 1.04)
Carcass Express Percentage Reduction		**25.2 %**

Table 4.3 illustrates the relative inventory availability statistics for NIIN 012328815 of the High Group. Over 16 quarters, statistics are shown for the current repair process, the simulated Carcass Express process, and the hypothesis test value. Standard error (SE) represents the precision of the simulation SD.

Table 4.4 Low Group Available Inventory Example

NIIN 013513373	Mean Available Inventory (DLR items/QTR)	Standard Deviation (DLR items/QTR)
Without Carcass Express	80.31	23.52
With Carcass Express	79.10	18.71
Average of the Simulation Standard Deviations (SDs)		19.09 (SE = 0.60)
Carcass Express Percentage Reduction		**20.4 %**

Table 4.4 illustrates the relative inventory availability statistics for NIIN 013513373 of the Low Group. Over 16 quarters, statistics are shown for the current repair process, the simulated Carcass Express process, and the hypothesis test value. Standard error (SE) represents the precision of the simulation SD.

The inventory available from repair when the Carcass Express program is used creates an inventory curve with smaller peaks and valleys, in other words, a smoother inventory curve. The effect of a smoother inventory curve is the ability to more closely meet the actual demand levels over time. In order to predict the amount of purchased DLR items required to fill the deficit between repair inventory and demand, the amount of surplus inventory by quarter was determined. The following formula was used to determine quarterly surplus inventory:

Surplus = Available Inventory – Demand

The amount of surplus available through the implementation of the Carcass Express program is much less variable than that of the existing repair cycle. Table 4.5 illustrates the variability reduction for the NIIN selected from each group. These NIINs were chosen because they represented the greatest inventory impact within their respective groups.

Table 4.5 High and Low Group Surplus Variability Reduction

NIIN	**Standard Deviation** (DLR items/QTR) **No Carcass Express**	**Standard Deviation** (DLR items/QTR) **With Carcass Express**	**Percent Reduction**
High Group NIIN	41.8	29.2	30.1 %
Low Group NIIN	20.0	16.7	16.5 %

Table 4.5 illustrates the specific standard deviation changes for NIIN 012328815 of the High Group and NIIN 013513373 of the Low Group.

Figures 4.9 and 4.10 illustrate the surplus for the DLR item selected from the High and Low Group exhibiting the highest inventory levels. The surplus is measured over the 16 -quarter period of analysis.

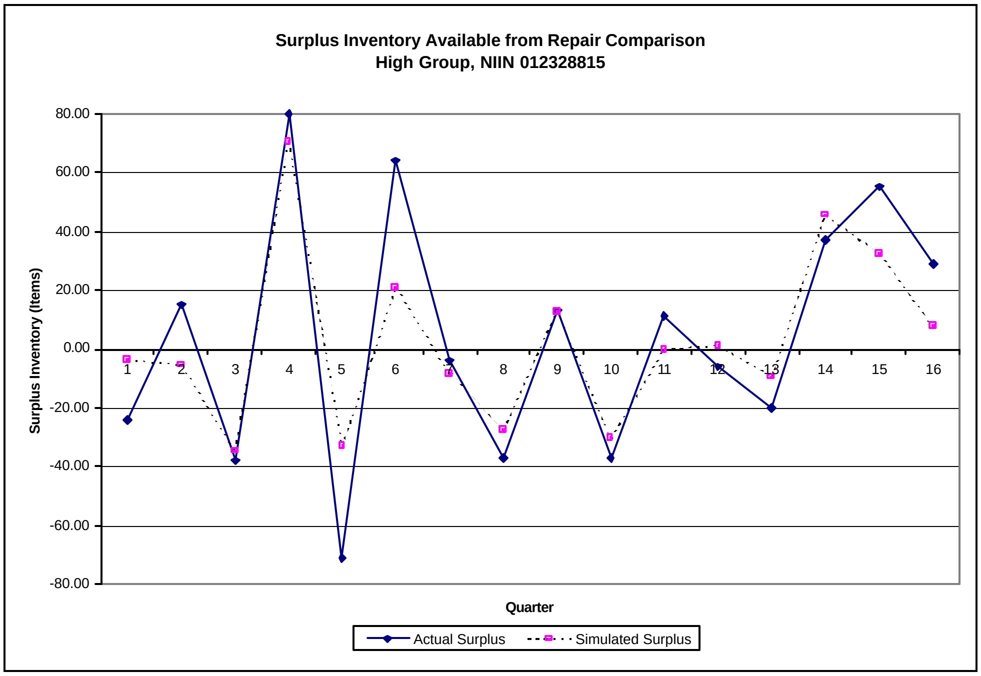


Figure 4.9 Simulated vs. Actual Surplus Inventory (High Group)

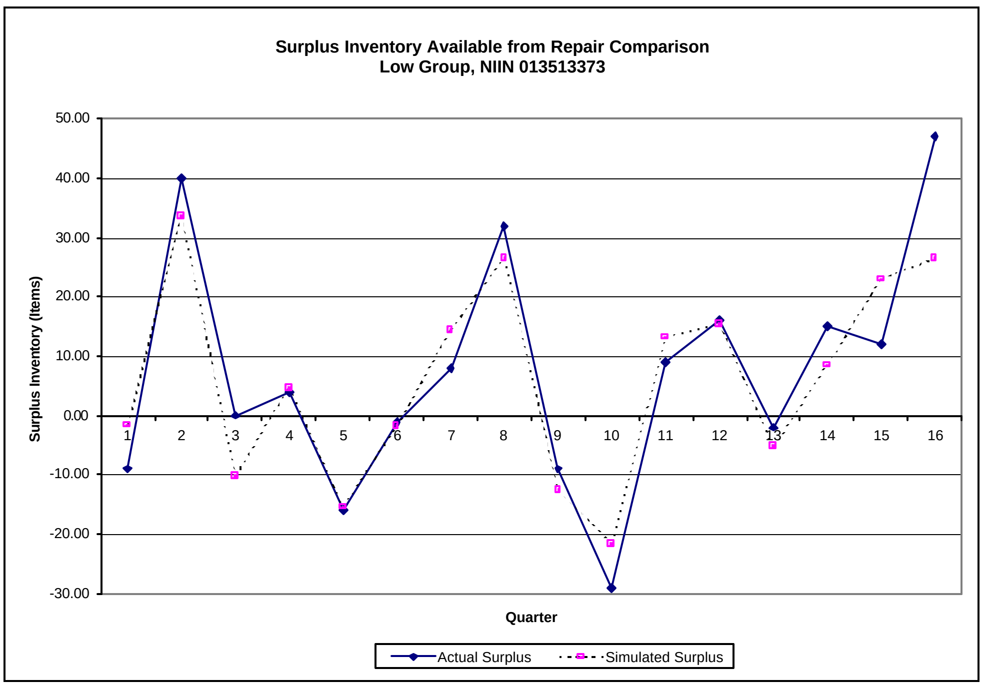


Figure 4.10 Simulated vs. Actual Surplus Inventory (Low Group)

F. INVENTORY PROCUREMENTS

Inventories exist because it is usually not possible to match the need for an item with availability of an item without them. In the military, there is no concept of profit on a sale. The profit is the utility of having a downed system restored to operation and fully mission capable. In the military inventory system, a demand that occurs when the bin is empty results in a backorder and a requisition is created. If demand were perfectly predictable, no inventory would be necessary. Random demand is the central feature of real inventory systems (Schrady, 1971). Variability and uncertainty are the two main reasons DoD attempts to maintain high inventory levels. In this thesis, direct demand was represented as discrete demand whereas forecast demand was continuous. Generally, demand is assumed to be continuous, but by making it discrete, the analysis becomes more consistent with the available data. Direct demand does not capture all of demand because DLR carcasses wear out over time requiring replacement. In a repairable inventory model with a discrete demand, the amount of procurement is substituted for that of repair (Schrady, 1971). Procurement must be initiated to fill the gap between the direct demand level and the amount of inventory available from repair. By calculating the amount of surplus for any given quarter, the amount of procurement is readily obtainable. The following formulation, established by NAVICP, was used to determine the amount of purchased DLR items required to meet the quarterly direct demands as defined earlier (Croll, 2000).

d = Quarterly demand
x = Quantity of Inventory returned from the repair system per quarter
x_p = Amount of Procurement combined with inventory carry over per quarter
S = Stock (Safety stock, computed to be 0.33*quarterly demand + quarterly demand)

$S = x + x_p$
$S = 1.33 * d$

Therefore,

$x_p = 1.33*d - x$

To reflect feasibility, use

$x_p = \max(1.33*d - x, 0)$

Using the formulas above, the amount of purchased DLR items required to meet the quarterly demand was determined. Figures 4.11 and 4.12 illustrate the average procurement required to meet the direct demand-supply deficit for both the current Depot Repair Cycle and the Depot Repair Cycle with the reduced transportation time provided by the Carcass Express program.

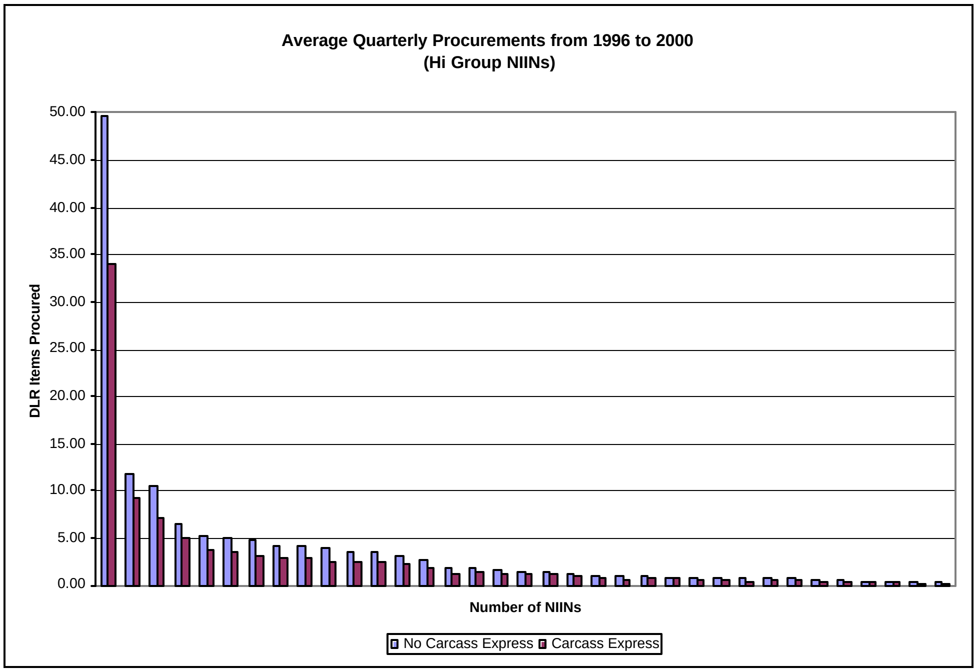


Figure 4.11 Average Quarterly Procurement for High Group DLRs

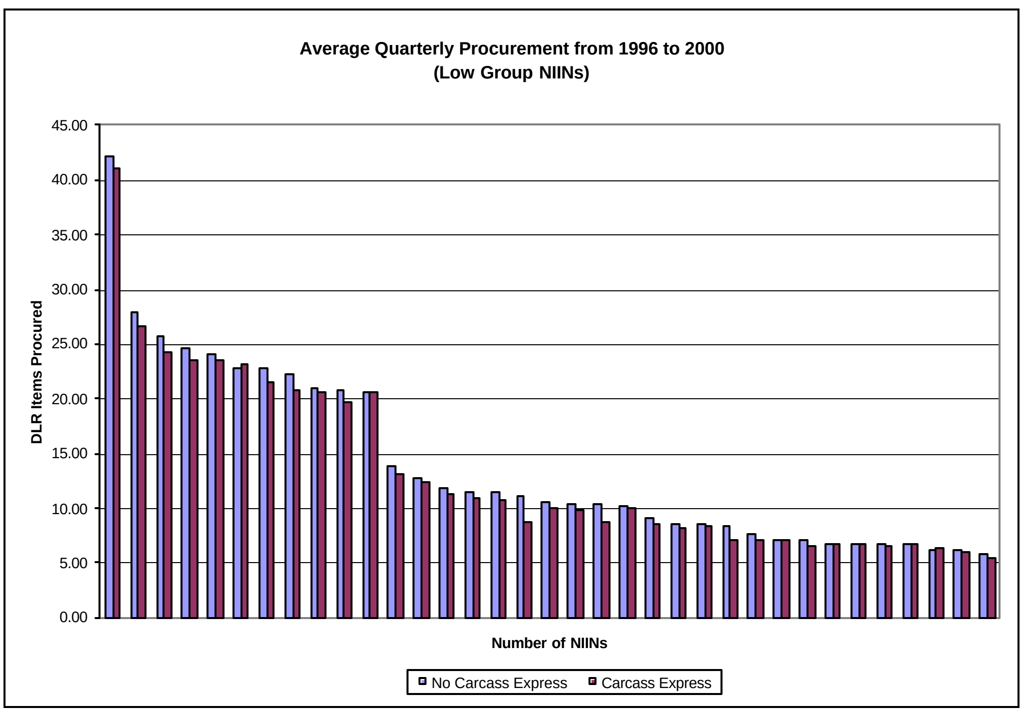


Figure 4.12 Average Quarterly Procurement for Low Group DLRs

Figure 4.12 illustrates the top 35 NIINs, based on the average number of procured DLR items each quarter, of the 150 low group NIINs.

Table 4.6 quantifies the potential value of additional inventory that can be realized by initiating the Carcass Express program on the 185 DLR items that were studied. The assumptions that are implicit in the calculations are as follows:

- Inventory has no carry-over capacity from quarter to quarter.
- Repairs that were completed in a given quarter produced inventory that was available in the following quarter.
- All demand must be met from repairs completed in the previous quarter.

Table 4.6 Potential Savings from 1996 to 2000 (16 Quarters)

	DLR Purchase Transactions	Extended Price
Without Carcass Express	13,055	$337,906,696
With Carcass Express	12,123	$308,997,451
	Total Savings	**$28,909,245**
	Percent Savings	**3.19 %**

Potential savings are based on the average scenario for all 185 NIINs using the Carcass Express model. The illustrated savings constitutes the cumulative procurements of DLRs required to meet the quarterly direct demand over the four-year period. The 16 quarters represents the time from Quarter 2, 1996 through Quarter 1, 2000. The extended price uses the standard price in FY2000 U.S. dollars. The percent savings represents the potential reduction in total inventory costs over the four-year period.

Table 4.6 demonstrates that an additional 3.19 percent of demand can be met purely from the additional inventory that becomes available in the previous quarter, due to the Carcass Express program.

Figure 4.13 provides an effective illustration that over the four-year time period analyzed in this thesis, the amount of procurement required to meet current stock levels is significantly reduced with the Carcass Express program.

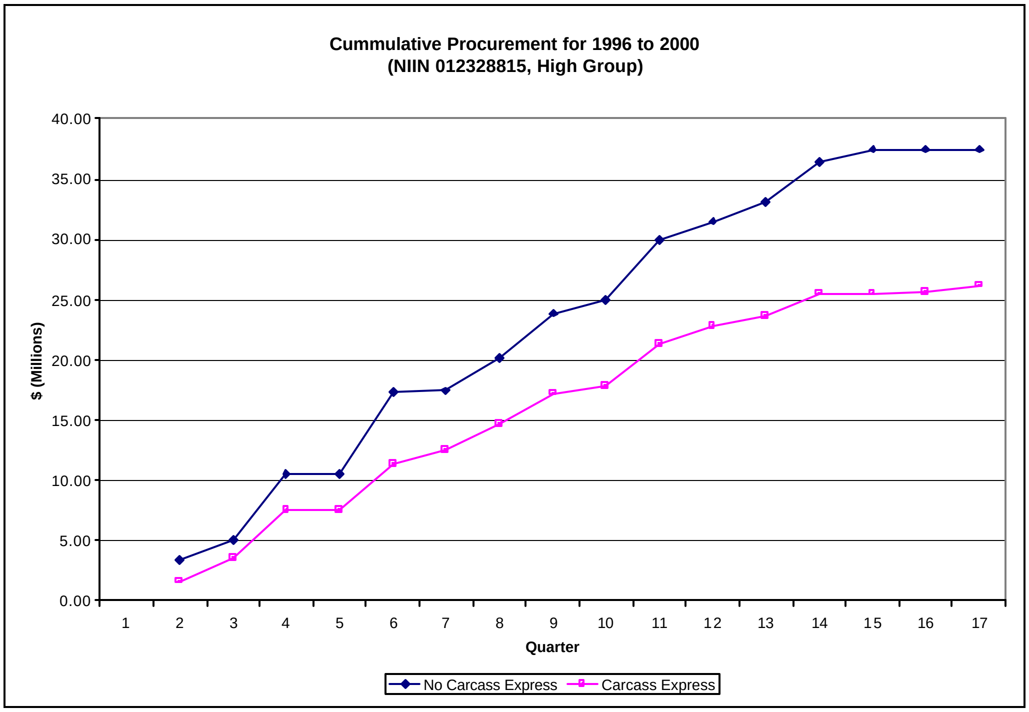


Figure 4.13 Procurement Costs Comparison by Quarter for High Group DLR

A summary of the findings by component category is presented in the following table.

Table 4.7 Estimated Total Savings over 16 Quarters

	Savings (FY2000 U.S. Dollars)	
	Median Transportation Time	
Component Category	High	Low
Circuit Boards (C)	1,088,236 (14.69%)	1,194,550 (2.15%)
Electrical (E)	4,359,109 (12.87%)	3,382,779 (1.18%)
Mechanical (M)	16,638,836 (14.72%)	2,245,735 (0.55%)
Total Savings		**$28,909,245** (3.19%)

Table 4.7 provides a breakdown of how each category of DLR items used in this analysis contribute to the overall procurement savings generated by the Carcass Express program. The savings realized is the difference between the extended prices of DLR items required to meet Direct Demand before and after Carcass Express. The percent savings represents the savings within each category related to the initial inventory costs. The direct demand does not represent a complete demand because it only considers the number of failed DLRs.

V. SUMMARY AND CONCLUSIONS

The 185 DLR items analyzed in this thesis constitute an aggregate inventory cost exceeding $900 million from 1996 to 1999. The Carcass Express program would produce an addition to inventory with a value estimated at $28.9 million over the same time period. This represents 3.19 percent of the total inventory cost. In addition to the cost savings, a significant decrease in inventory variability would be realized throughout the Depot Repair Cycle. NAVICP inventory managers must consider factors such as unstable demand, huge stockout costs, and geographic dispersion when developing inventory management practices. A reduction in inventory variability will further increase the inventory savings in future years. Reducing variability within inventory systems saves money and reduces the amount of money spent through purchasing. This thesis demonstrated that by reducing the cycle times within the Depot Repair Cycle, the amount of inventory available from repair can be predicted in addition to what procurement will be required to fill the supply and demand deficit.

The analysis presented in this thesis makes several key assumptions. Any deficit between demand and available inventory from repair must be met with purchased DLR items. No carry over of surplus inventory from repair was used to meet demand of the next quarter. The financial obligation required to meet demands is solely based on a quarter-by-quarter basis dependent on the deficit.

Extrapolating the savings directly to the entire set of DLR items representing the Carcass Express program is not possible with the data that was obtained from NAVICP for this thesis. A more elaborate inventory model is needed. The data analyzed for this

thesis could not be used to determine quarter-by-quarter procurement and demand levels. Initial inventory positions, and increments and decrements to inventory in real-time were not available for the thesis research. A more thorough investigation is required to more precisely quantify the reduction in back-order level and the amount of materiel that Carcass Express will provide to the F/A-18 repair program.

The Carcass Express program brings DLR carcasses to the depot at a faster rate. The NADEPs have demonstrated an ability to manage additional workload so as not to be overburdened by the increased repair requirements created by the Carcass Express program. The ability to accommodate customers and meet the repairs most critical to military readiness is the focus of the NADEP organizations.

APPENDIX A: SOFTWARE USED FOR ANALYSIS

The S-Plus functions that follow were used to produce the Depot Repair Cycle elements to forecast the inventory available with the implementation of the Carcass Express program. The first function shown is the resultant simulation for both Group 1 and Group 2 NIINs. Arguments to **SimulationHi** and **SimulationLo** consist of the following:

- *rHi*: an S-plus data frame of observations illustrating the RTAT completion date, as defined in chapter 4, associated with each NIIN in group 1.
- *rLo*: an S-plus data frame of observations illustrating the RTAT completion date, as defined in chapter 4, associated with each NIIN in group 2.
- *transHi*: an S-plus data frame consisting of a vector of original transportation times associated with each NIIN in group 1.
- *transLo*: an S-plus data frame consisting of a vector of original transportation times associated with each NIIN in group 2.
- *qbins*: an S-plus data frame illustrating the dates representing each quarter from quarter 1 of 1996 to quarter 1 of 2000. Figure 4.2 shows the resultant data frame.

The remaining functions were used to develop the NIINs of Group 1 and Group 2 and to establish the Transportation Times, RTAT and other flows within the NADEP flow chart shown in figure 3.1.

```
Function name: SimulateHi
function()
{
#
##########################################################################
# This function (SimulateHi) creates a simulated response of the available
# inventory by quarter beginning with 1996 quarter 1. The completion dates
# from the RTAT data is provided in the rHi data set.
# The data provided has already been developed
# for use in the program. We will simulate time frames from
# the transportation time of the DLR pipeline, reduced by 29/39, and
# utilize the resultant values to determine when inventory would become
```

```
#  available based on the given RTAT for the specific NIINs in the Hi-median group.
#
#  SDG 04-22-01
#
#  rHi is the final Rtat completion dates for the transportation data
#  represented in the high-median group.  Each COMPDT corresponds
#  to a unique NIIN.
########################################################################

#
        reduced.transHi <- round(((29/39) * (transHi)), 0)
        # Number used to reduced COMPDT to 10 Days of original Transporation Time
#
        qHi0 <- pmin(cut(rHi[, 2], qbins) + 1, 18)     # Original Bin Membership
        qHi0tab <- table(as.character(rHi[, 1]), qHi0)
        nHi <- dim(rHi)[1]          #
        negcut <- 0
        Qavg <- matrix(0, 35, 17)
        Qsd <- Qavg
        qtauHibar <- numeric(35)
        qtauHiSd <- numeric(35)   #
#
#  Begin Simulation Here:
        nsim <- 1000
        for(i in 1:nsim) {
                xHi <- sample(reduced.transHi, nHi, replace = T)
                newHi <- pmax(rHi[, 2] - xHi, 5)     # RTATs less than 5 days are invalid
                qHi <- pmin(cut(newHi, qbins) + 1, 18)
                qtabNew <- matrix(0, 35, 17)
                qcol <- sort(unique(qHi)) - 1
                qtabNew[, qcol] <- round(table(as.character(rHi[, 1]), qHi), 0)
                qtauHi <- apply(qtabNew[, 2:17], 1, stdev)
                qtauHibar <- qtauHibar + qtauHi
                qtauHiSd <- qtauHiSd + qtauHi^2
                Qavg <- Qavg + qtabNew
                Qsd <- Qsd + qtabNew^2  ###
#       cat("Completed Iteration", i, "\n")
                negcut <- negcut + sum(newHi == 1)
        }
        qtauHibar <- qtauHibar/nsim
        qtauHiSd <- qtauHiSd/nsim
        Qavg <- Qavg/nsim
        Qsd <- sqrt((Qsd - nsim * Qavg^2)/(nsim - 1))
        dimnames(qtabNew) <- list(NULL, c(1:17))
        dimnames(Qavg) <- list(NULL, c(1:17))
        dimnames(Qsd) <- list(NULL, c(1:17))
        return(list(qtabNew = qtabNew, Qavg = Qavg, Qsd = round(Qsd, 2), qHi0tab = qHi0tab, negcuts
= negcut, qtauHibar = qtauHibar, qtauHiSd = qtauHiSd))
}
```

Function name: SimulateLo

```
function()
{
########################################################################
```

```
#  This function (SimulateLo) creates a simulated response of the available
#  inventory by quarter beginning with 1996 quarter 1.  The completion dates
#  from the RTAT data is provided in the rLo data set.
#  The data provided has already been developed
#  for use in the program.  We will simulate time frames from
#  the transportation time of the DLR pipeline, reduced by 29/39, and
#  utilize the resultant values to determine when inventory would become
#  available based on the given RTAT for the specific NIINs in the Lo-median group.
#
#  SDG 06-10-01
#
#  rLo is the final Rtat completion dates for the transportation data
#  represented in the low-median group.  Each COMPDT corresponds
#  to a unique NIIN.
########################################################################
#
        reduced.transLo <- round(((29/39) * (transLo)), 0)      # Number used to reduced COMPDT to 10
Days of original Transporation Time
#
        qLo0 <- pmin(cut(rLo[, 2], qbins) + 1, 18)     # Original Bin Membership
        qLo0tab <- table(as.character(rLo[, 1]), qLo0)
        nLo <- dim(rLo)[1]           #
        negcut <- 0
        Qavg <- matrix(0, 150, 17)
        Qsd <- Qavg
        qtauLobar <- numeric(150)
        qtauLoSd <- numeric(150)   #
#
#  Begin Simulation Here:
        nsim <- 100
        for(i in 1:nsim) {
                xLo <- sample(reduced.transLo, nLo, replace = T)
                newLo <- pmax(rLo[, 2] - xLo, 5)   # RTATs less than 5 days are invalid
                qLo <- pmin(cut(newLo, qbins) + 1, 18)
                qtabNewLo <- matrix(0, 150, 17)
                qcol <- sort(unique(qLo)) - 1
                qtabNewLo[, qcol] <- round(table(as.character(rLo[, 1]), qLo), 0)
                qtauLo <- apply(qtabNewLo[, 2:17], 1, stdev)
                qtauLobar <- qtauLobar + qtauLo
                qtauLoSd <- qtauLoSd + qtauLo^2
                Qavg <- Qavg + qtabNewLo
                Qsd <- Qsd + qtabNewLo^2
                cat("Completed Iteration", i, "\n")
                negcut <- negcut + sum(newLo == 1)
        }
        qtauLobar <- qtauLobar/nsim
        qtauLoSd <- qtauLoSd/nsim
        Qavg <- Qavg/nsim
        Qsd <- sqrt((Qsd - nsim * Qavg^2)/(nsim - 1))
        dimnames(qtabNewLo) <- list(NULL, c(1:17))
        dimnames(Qavg) <- list(NULL, c(1:17))
        dimnames(Qsd) <- list(NULL, c(1:17))
        return(list(qtabNewLo = qtabNewLo, Qavg = Qavg, Qsd = round(Qsd, 2), qLo0tab = qLo0tab,
negcut = negcut, qtauLobar = qtauLobar, qtauLoSd = qtauLoSd))
}
```

Function name: invfunk

```
function(inv.df)
{
###########################################################################
#  This function (invfunc) determines the met demand based on the inventory available
#  from the RTAT.  The RTAT inventory available must have columns identified by
#  yyQ (year, quarter) prior to applying this function.
#
#  SDG/Buttrey 04-23-01
###########################################################################
	result <- matrix(0, nrow(inv.df), 17)
	dimnames(result) <- list(NULL, c("961", "962", "963", "964", "971", "972", "973", "974", "981",
"982",
		"983", "984", "991", "992", "993", "994", "001"))	#
	qs.minus.3 <- substring(qs, 4, nchar(qs))	#
#
# "i" goes from 1 to 17 and names the "qs" element (e.g. "dem961")
# being used. "start" goes from ncol(inv.df) - 16 to ncol(inv.df) and
# indexes the relevant column of inv.df. This is how we handle the
# case where inv.df has more than 17 columns -- but we require that
# the demands be in the last 17 columns.
#
	start <- ncol(inv.df) - 16
	if(any(names(inv.df) == "NIIN"))
		in.niins <- inv.df$NIIN
	else if(any(names(inv.df) == "niin"))
		in.niins <- inv.df$niin
	else stop("No niin column. You suck.")
	for(i in 1:length(qs)) {
		dem <- get(qs[i])
		dd <- dem[match(in.niins, dem$NIIN), "Qtr"]
		cat("Operating on ", qs[i], ", start =", start, "\n")
		inv <- inv.df[, start]		#
###		inv <- inv.df[[qs.minus.3[i]]]
		out <- numeric(length(inv))
		out[inv > dd] <- 1
		index <- (1:length(inv))[inv <= dd]
		out[index] <- round(1 - (dd[index] - inv[index])/dd[index], 2)
		result[, i] <- out
		start <- start + 1
	}
	if(any(dimnames(inv.df)[[2]] == "niin"))
		result <- data.frame(NIIN = I(as.character(as.vector(inv.df$niin))), result)
	else if(any(dimnames(inv.df)[[2]] == "NIIN"))
		result <- data.frame(NIIN = I(as.character(as.vector(inv.df$NIIN))), result)
###names(result) <- c("961", "962", "963", "964", "971", "972", "973", "974", "981", "982", "983", "984", "991", "992", "993
###
return(result)
}
```

Function name: Demand

```
###############################################################################
```

```
#  This script file (Demand) will take the quarterly demand data from the UICP model
#  and filter the columns utilized in analysis.  The columns are extracted and placed
#  into a data frame.
##########################################################################################
#  SDG 03-05-01
#
#

D  <-
data.frame(file[,'NIIN'],file[,'QTRLY.DEMAND'],file[,'A023'],file[,'B011A'],file[,'B022'],file[,'B022B'],fil
e[,'F007'],file[,'F009'],file[,'B012E'])

names(D) <- c('NIIN', 'Qtrly.Dem', 'DEM.Rqn', 'PLT', 'RandMaint.Dem', 'AvgCarc.Rtn', 'WOR', 'RSR',
'AVG.RTAT')

return(D)
```

Function name: Combine

```
############################################################################################
#  This file (Combine) will take combined data sets and create a new data set showing only the unique
NIINs and their respective frequency and other information as provided.
############################################################################
#
#  Note: The invRTAT file is created with 'rbind()' on all 'inv' data sets.
#
#  SDG 02-27-01
#

niin <- sort(unique(invRTAT[,1]))
n <- length(niin)
C <- data.frame(niin,matrix(0,n,18))
for (j in 1:n)  {
        tt <- invRTAT[,1]==niin[j]
        C[j,2:19] <- apply(invRTAT[tt,2:19],2,sum)
        cat("combining the data sets on iteration ",j,'\n')
}
names(C)[2:19] <- c("Freq", "961", "962", "963", "964", "971", "972", "973", "974", "981", "982", "983",
"984", "991", "992", "993",
                "994", "001")
```

Function name: dateConvert

```
function(file)
{
###########################################################################
#  This function (dateConvert) converts a vector of dates in YYDDD
#  format located in the file document to the number of days since 1 January 1960.
#  The file is returned in the with the new dates replacing the YYDDD format
#
#  SDG 4-8-01
############################################################################
#
        n <- dim(file)[1]
```

```
        for (j in 1:n) {
                cyr <- floor(0.001 * file[j,"COMPDT"])
                cda <- file[j,"COMPDT'] - 1000 * cyr
                djul <- julian(12, 31, 1900 + cyr - 1) + cda
                file[j,'COMDT'] <- djul

        }
        return(file)
}
```

Function name: jdate

```
function(jdate)
{
######################################################################
#  This function accepts a vector of dates consisting of YDDD and
#  retruns a Julian Date based on 1 January 1960.
#
#  Y = last digit of a year where 1 = 1991, ...., 9 = 1999, 0 = 2000.
#
#  This function allows one to determine the difference between Julian Dates
#  in order to determine time between specific Julian Dates
#
#  SDG 02-11-01
#########################################################################
        y <- floor(jdate/1000)
        ndays <- jdate - 1000 * y - 1
        y[is.na(y)] <- -1
        newdate <- rep(NA, length(jdate))
        for (j in 1:9) {
                tt <- y == j
                if (any(tt)) {
                        mdy <- month.day.year(ndays[tt], c(1,1,1990 + j))
                        newdate[tt] <- julian(mdy[[1]], mdy[[2]], mdy[[3]])
                }
        }
        tt <- y == 0
        if(any(tt)) {
                mdy <- month.day.year(ndays[tt], c(1,1,2000))
                newdate[tt] <- julian(mdy[[1]], mdy[[2]], mdy[[3]])
        }
        return(newdate)
}
```

Function name: makeQtr

```
function(x, nextqtr = T)
{
#####################################################################
#  This function (makeqtr) takes a vector of julian dates and
#  returns a two-item vector showing the year and quarter.
#
#  Y[,1] = year (last 2 digits)
#  Y[,2] = quarter (1, 2, 3, 4)
```

```
#
#  If nextqtr = T, then the function will return the following quarter.
#  (This will impact "rtatNIIN' and show inventory in the following qtr.
#
#  SDG 2-11-01
###################################################################
	yr <- floor(0.001 * x)
	n <- length(x)
	qtr <- numeric(n)
	nodays <- x - 1000 * yr      # Returns number of days in the year
	tt <- yr == 96 | yr == 0
	if(any(tt)) {
		qtr[tt & nodays < 92] <- 1
		qtr[tt & nodays >= 92 & nodays < 183] <- 2
		qtr[tt & nodays >= 183 & nodays < 275] <- 3
		qtr[tt & nodays >= 275] <- 4
	}
	if(any(!tt)) {
		qtr[!tt & nodays < 91] <- 1
		qtr[!tt & nodays >= 91 & nodays < 182] <- 2
		qtr[!tt & nodays >= 182 & nodays < 274] <- 3
		qtr[!tt & nodays >= 274] <- 4
	}
	if(nextqtr) {
		tt <- qtr < 4
		if(any(tt)) {
			qtr[tt] <- tr[tt] + 1
		}
		if(any(!tt)) {
			qtr[!tt] <- 1
			yr[!tt] <- yr[!tt] + 1
		}
	}
	xdate <- cbind(yr, qtr)
	dimnames(xdate) <- list(NULL, c("yr", "qtr"))
	return(xdate)
}
```

Function name: Match_script

```
#####################################################################################
# Matching files against the Carcass Express NIINs
#
#  This script takes a file with a column of NIINs and outputs a new dataframe with only the applicable
NIIN information.
#  The information can then be used to conduct further analysis.
#
# SDG 02-20-01
#####################################################################################

  tmatch <- match(XB99[,'NIIN'], express[,'carcexpniin'])
	tt <- !is.na(tmatch)
	tat99 <- XB99[tt,]
```

Function name: Quantile_script

```
####################################################################################
# Creating Quartiles from a given data base
#
#  This script takes a file with a column of NIINs and computes the 25th, 50th, and 75th Quartiles.
#  The 50th is also the median.
#
# SDG 01-20-01
####################################################################################
	A <- data.frame(nunique, ntab)
#	ddate <- makeJulianDT(as.numeric(transTime[, "HUBRECVDT"])) - 
makeJulianDT(as.numeric(transTime[, "JULIANDT"]))
	for(j in 1:n) {
		tt <- Y[, "NIIN"] == nunique[j]
		A[j, 3:5] <- quantile(tdate[tt], c(0.25, 0.5, 0.75), na.rm = T)
		cat("Computing Quantiles at iteration", j, "\n")
	}
	names(A)[3:5] <- c("Q.25", "Q.50", "Q.75")
#	return(A)
```

Function name: qQuants

```
function(file)
{
#########################################################################
#  This function (qQuants) takes a file with a column of NIINs and
#  computes the 25th, 50th, and 75th Quartiles.  The 50th is
#  also the median.
#
# SDG 01-20-01
#########################################################################
	nunique <- sort(unique(file[, "NIIN"]))
	n <- length(nunique)
	ntab <- table(file[, "NIIN"])
	A <- data.frame(nunique, ntab)
	ddate <- makeJulianDT(as.numeric(file[, "HUBRECVDT"])) - makeJulianDT(as.numeric(file[, 
"JULIANDT"]))
	for(j in 1:n) {
		tt <- file[, "NIIN"] == nunique[j]
		A[j, 3:5] <- quantile(ddate[tt], c(0.25, 0.5, 0.75), na.rm = T)
		cat("Computing Quantiles at iteration", j, "\n")
	}
	names(A)[3:5] <- c("Q.25", "Q.50", "Q.75")
	return(A)
}
```

Function name: RemoveDupes

```
function(X)
{
##########################################################################
#  This function (RemoveDupes) works exclusively for the
#  demand data file (demandSTATS) to remove duplicate
```

```
#  entries.  The resultant vector will identify
#  a file with only non-repeated NIIN entries.
#
#  The data file (X) must be ordered prior to operating
#  this function.
#
#  3-3-01
##########################################################################
	n <- dim(X)[1]
	tuse <- rep(F, n)
	tuse[1] <- T
	x0 <- X[1,  ]
	for(j in 1:n) {
		if(any(X[j,  ] != x0)) {
			tuse[j] <- T
			x0 <- X[j,  ]
		}
	}
	return(tuse)
}
```

Function name: lowTAT

```
function(Qfile, rtatFile)
{
######################################################################
#  This function (lowTAT) takes a file (Qfile) representing a group of NIINs
#  with their respective Quantiles and matches them to the repair time
#  file (rtatFile).  We subtract the (29/39)*median of each NIIN in the Qfile from
#  the TAT of the same NIIN.  (29/39) represents a 10 day reduction in delivery
#  time of any given NIIN.  The output should be the reduction in days of RTAT.
#
# SDG 02-05-01
######################################################################

	n <- length(rtatFile)
	for(j in 1:n) {
		if (rtatFile[j,'NIIN'] == Qfile["nunique"]) {
			tt <- rtatFile[j,'TAT'] - (29/39)* Qfile['Q.5']
			A[j, 6] <- tt[j]
			cat("Computing times at iteration", j, "\n")
		}
		else {
			cat('No TAT found',j,'\n')
		}
	}
	return(A[1:5,  ])
}
```

Function name: rtatNIIN

```
function(file)
{
#################################################################
```

```
#  This function (rtatNIIN) compares the NIINs of an RTAT
#  database to those of the express NIINs and returns a
#  dataframe with those NIINs and the associated
#  completion quarters.  This will show what quarter
#  inventory becomes available for a specific NIIN.
#
#  Data provided must be RTAT data with the column
#  'COMPDT' shown. A table will be output containing the quarters
#  represented in the RTAT data sets.
#
#  SDG 2-7-01
##############################################################

	tmatch <- match(file[, "NIIN"], express[, "carcexp niin"])
	tt <- !is.na(tmatch)
	uniin <- sort(unique(file[tt, "NIIN"]))
	n <- length(uniin)
	B <- data.frame(uniin, matrix(0, n, 18))
	B[, 2] <- table(file[tt, "NIIN"])
	qvals <- c(961, 962, 963, 964, 971, 972, 973, 974, 981, 982, 983, 984, 991, 992,
		993, 994, 001)
	for(j in 1:n) {
		y <- file[, "NIIN"] == uniin[j]
		cat("Begin MAKEQTR for NIIN ", j, "\n")
		z <- makeqtr(file[y, "COMPDT"])
		qtr <- 10 * z[, 1] + z[, 2]
		qtab <- table(qtr)
		quniq <- sort(unique(qtr))
		tq <- match(qvals, quniq)
		B[j, (3:19)[!is.na(tq)]] <- qtab
		cat("Finished NIIN ", j, "\n")
	}
	names(B)[2:19] <- c("Freq", "961", "962", "963", "964", "971", "972", "973", "974", "981", "982",
"983", "984", "991", "992", "993",
		"994", "001")

	return(B)
}
```

Function name: tatMedian

```
function(file)
{
###############################################################
#  This function takes a file with a column of NIINs and
#  computes the 50th Quartile on the TATs.  The 50th is
#  also the median.
#
#  We can pair down any given RTAT data frame as well matching
#  the functions.
#
# SDG 01-20-01
###############################################################

	nunique <- sort(unique(file[, "NIIN"]))
```

```
        n <- length(nunique)
        B <- data.frame(nunique)
        tat <- as.numeric(file[,'TAT])
        for(j in 1:n) {
                tt <- file[, "NIIN"] == nunique[j]
                B[j, 2] <- quantile(tat[tt], 0.5, na.rm = T)
                cat("Computing Quantile at iteration", j, "\n")
        }
        names(B)[2] <- c("Q.50")
        return(B[1:5,  ])
}
```

Function name: tatConvert

```
function(file)
{
##################################################################################
#  This function (tatConvert) converts a vector of dates in YYDDD
#  format located in the file document (ie. tat98) to the number of days since
#  1 January 1960.  The file is returned in with the new dates replacing the
#  YYDDD format.
#
#  Note:  The original file must have a column ‘COMPDT’ in YYDDD format.
#
#  SDG 4-8-01
##################################################################################
#
        X <- file[!is.na(match(file[, "NIIN"], finalNIIN)),  ]
        n <- dim(X)[1]
        D <- data.frame(X[, "NIIN"], matrix(0, n, 1))
        for(j in 1:n) {
                cyr <- floor(0.001 * X[j, "COMPDT"])
                cda <- X[j, "COMPDT"] - 1000 * cyr
                djul <- julian(12, 31, 1900 + cyr) + cda
                D[j, 2] <- djul
                cat("Converting COMDT at iteration", j, "\n")
        }
        names(D) <- c("NIIN", "COMPDT")
        return(D)
}
```

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APPENDIX B: DLR PARTS USED IN THE ANALYSIS

Tables B.1 and B.2 identify which depot level repairable parts were used in the analysis. The tables are segregated into groups. The High Group identifies the DLR items that exhibited a median transportation time greater than 20 days. The Low Group identifies the DLR parts that exhibited a median transportation time less than or equal to 20 days. The Standard price reflects prices in year 2000 dollars. The initial available inventory is the aggregate inventory, by NIIN, from quarter 1 of 1996 through quarter 1 of 2000.

Table B.1 DLR Parts Assigned to the High Group

	NIIN	NOMENCLATURE	Class	Std Price (FY2000) Dollars	Completed Repairs 1996-1999	Extended Price (FY2000) Dollars
1	011076858	ADAPTER, HOLDBACK	M	15,590	99	1,543,410
2	011076903	ARM ASSEMBLY, TORQUE	M	4,540	34	154,360
3	011403914	ACCUMULATOR ASSEMBLY	M	34,580	202	6,985,160
4	011407773	POWER SUPPLY	E	24,340	104	2,531,360
5	011506731	CYLINDER AND PISTON	M	151,910	140	21,267,400
6	011567310	DISPLAY UNIT, HEAD-UP	E	94,160	307	28,907,120
7	011614423	ELECTRONIC COMPONENT	E	4,610	24	110,640
8	011827976	PANEL, CONTROL	E	7,410	113	837,330
9	011987689	ADAPTER ASSEMBLY, SWITCH	E	3,050	74	225,700
10	012238121	CYLINDER, LANDING	M	71,440	13	928,720
11	012265338	POWER SUPPLY SUBASSEMBLY	E	12,810	53	678,930
12	012265381	CIRCUIT CARD ASSEMBLY	C	4,610	7	32,270
13	012313037	CIRCUIT CARD ASSEMBLY	C	10,380	137	1,422,060
14	012328815	HOOK SUBASSEMBLY, ARM	M	50,370	1,570	79,080,900
15	012343583	CIRCUIT CARD ASSEMBLY	C	4,610	15	69,150
16	012364963	TRANSMISSION, MECHANICAL	M	33,060	4	132,240
17	012382687	CIRCUIT CARD ASSEMBLY	C	7,010	86	602,860
18	012405702	TRANSMISSION, MECHANICAL	M	94,560	11	1,040,160
19	012429698	PANEL, FAULT -FUNCTION	E	17,760	33	586,080
20	012432688	CIRCUIT CARD ASSEMBLY	C	4,610	36	165,960
21	012517280	CIRCUIT CARD ASSEMBLY	C	6,240	359	2,240,160
22	012830295	CIRCUIT CARD ASSEMBLY	C	6,260	11	68,860
23	012830296	CIRCUIT CARD ASSEMBLY	C	7,590	13	98,670
24	012938976	CIRCUIT CARD ASSEMBLY	C	4,610	26	119,860
25	012938980	CIRCUIT CARD ASSEMBLY	C	6,750	51	344,250
26	012938986	CIRCUIT CARD ASSEMBLY	C	4,610	102	470,220

	NIIN	NOMENCLATURE	Class	Std Price (FY2000) Dollars	Completed Repairs 1996-1999	Extended Price (FY2000) Dollars
27	012982163	CIRCUIT CARD ASSEMBLY	C	4,610	161	742,210
28	012982164	CIRCUIT CARD ASSEMBLY	C	4,610	20	92,200
29	012990335	CIRCUIT CARD ASSEMBLY	C	6,000	144	864,000
30	013110271	LOCK AND FLAG ASSEMBLY	M	4,860	7	34,020
31	013130125	LEVER ASSEMBLY, AXLE	M	35,010	20	700,200
32	013130126	LEVER ASSEMBLY, AXLE	M	35,000	14	490,000
33	013360464	HEAD ASSEMBLY, READ	M	22,400	17	380,800
34	013421493	CIRCUIT CARD ASSEMBLY	C	7,650	10	76,500
35	013983984	COLLAR AND GEAR ASSEMBLY	M	22,210	13	288,730
					Total	$**154,312,490**

Table B.2 DLR Parts Assigned to Low Group

#	NIIN	NOMENCLATURE	Class	Std Price (FY2000) Dollars	Completed Repairs 1996-1999	Extended Price (FY2000) Dollars
1	011136033	DAMPER, CYLINDER ASSEMBLY	M	15,370	246	3,781,020
2	011148768	CIRCUIT CARD ASSEMBLY	C	12,180	22	267,960
3	011148770	CIRCUIT CARD ASSEMBLY	C	4,940	34	167,960
4	011148771	CIRCUIT CARD ASSEMBLY	C	12,180	30	365,400
5	011148798	ACCUMULATOR, HYDRAULIC	M	22,160	123	2,725,680
6	011161283	FAN, VANEAXIAL	M	12,350	238	2,939,300
7	011168653	ACTUATOR, ELECTRO-MECHANICAL	M	9,220	265	2,443,300
8	011257346	SERVOVALVE, HYDRAULIC	M	7,770	201	1,561,770
9	011257935	PROBE ASSEMBLY, INFL	M	15,350	11	168,850
10	011257965	PANEL, CONTROL	E	7,410	7	51,870
11	011258153	CIRCUIT CARD ASSEMBLY	C	4,610	4	18,440
12	011395544	CARTRIDGE, MAGNETIC	M	39,720	404	16,046,880
13	011403594	ELECTRONIC COMPONENT	E	10,500	26	273,000
14	011404042	PANEL ASSEMBLY, CONT	E	11,900	388	4,617,200
15	011424304	VALVE ASSEMBLY, ELECTRICAL	M	3,870	2,015	7,798,050
16	011424347	SERVOVALVE, HYDRAULIC	M	9,170	1,001	9,179,170
17	011435655	VALVE ASSEMBLY, FAIL	M	5,300	1,102	5,840,600
18	011435781	CYLINDER ASSEMBLY	M	7,700	71	546,700
19	011435825	ELECTRONIC COMPONENT	E	22,930	120	2,751,600
20	011435887	CIRCUIT CARD ASSEMBLY	C	6,610	115	760,150
21	011440132	SERVOCYLINDER	M	32,900	503	16,548,700
22	011440203	CIRCUIT CARD ASSEMBLY	C	6,430	152	977,360
23	011440225	TRANSMISSION, MECHANICAL	M	40,420	67	2,708,140
24	011468339	HYDRAULIC UNIT, FILTER	M	17,000	115	1,955,000
25	011506863	POWER SUPPLY	E	6,580	21	138,180
26	011518139	CONTROL UNIT, THROTTLE	M	10,330	135	1,394,550
27	011520445	SOLENOID VALVE, SPEC	M	6,950	198	1,376,100
28	011526034	CONTROL UNIT ASSEMB	M	20,020	62	1,241,240
29	011544774	HEAT EXCHANGER, FUEL	M	4,880	271	1,322,480
30	011560811	SENSOR ASSEMBLY, RAT	E	74,770	46	3,439,420
31	011589694	SERVOCYLINDER	M	30,490	246	7,500,540
32	011589695	AMPLIFIER ASSEMBLY	E	6,190	94	581,860
33	011603886	POWER SUPPLY	E	6,480	134	868,320
34	011618376	VOLTMETER	E	4,220	213	898,860
35	011629281	MODULE, LAMP	E	36,800	214	7,875,200
36	011635407	PISTON ASSEMBLY	M	13,070	32	418,240
37	011636062	HOLDBACK BAR, REPEAT	M	23,480	497	11,669,560
38	011684838	CIRCUIT CARD ASSEMBLY	C	9,310	28	260,680
39	011684842	CIRCUIT CARD ASSEMBLY	C	4,610	60	276,600
40	011729643	TRANSIENT SUPPRESSOR	M	5,010	61	305,610
41	011757166	CIRCUIT CARD ASSEMBLY	C	4,610	45	207,450
42	011771963	SERVOVALVE ASSEMBLY	C	32,980	497	16,391,060
43	011774925	ENCODER-DECODER, COM	E	14,610	44	642,840

#	NIIN	NOMENCLATURE	Class	Std Price (FY2000) Dollars	Completed Repairs 1996-1999	Extended Price (FY2000) Dollars
44	011855009	CIRCUIT CARD ASSEMBLY	C	5,380	27	145,260
45	011861399	MOTOR, ROLL DRIVE	M	3,920	517	2,026,640
46	011861433	CONTROL, TEMPERATURE	M	21,400	214	4,579,600
47	011861465	SCANNER ASSEMBLY, OP	E	43,990	213	9,369,870
48	011861619	DRIVE ASSEMBLY, DERO	M	37,450	585	21,908,250
49	011861629	RECEIVER, INFRARED	E	295,280	206	60,827,680
50	011861672	DRIVE UNIT, HYDRAULIC	M	54,010	846	45,692,460
51	011882968	VALVE, LINEAR, DIRECT	M	6,010	71	426,710
52	011987705	SERVOVALVE, HYDRAULIC	M	4,820	1,178	5,677,960
53	012015528	CIRCUIT CARD ASSEMBLY	C	6,480	225	1,458,000
54	012027294	CYLINDER ASSEMBLY	C	13,680	73	998,640
55	012027295	CYLINDER ASSEMBLY	C	8,120	41	332,920
56	012100154	POWER SUPPLY	E	13,420	479	6,428,180
57	012155725	ELECTRONIC COMPONEN	E	5,740	174	998,760
58	012155729	CIRCUIT CARD ASSEMBLY	C	6,540	306	2,001,240
59	012196324	HOUSING ASSEMBLY,GE	M	13,770	4	55,080
60	012204432	BAR, CATAPULT LAUNCH	M	7,930	223	1,768,390
61	012204858	CIRCUIT CARD ASSEMBLY	C	9,310	10	93,100
62	012238234	ARM ASSEMBLY, TORQUE	M	4,100	18	73,800
63	012265430	BLANKER, INTERFERENCE	E	112,260	39	4,378,140
64	012268606	CIRCUIT CARD ASSEMBLY	C	4,610	22	101,420
65	012292417	VALVE ASSEMBLY, CONT	M	65,130	430	28,005,900
66	012328865	PANEL ASSEMBLY, FRONT	E	11,870	278	3,299,860
67	012329009	TURBINE, AIRCRAFT CO	M	37,580	924	34,723,920
68	012329147	CIRCUIT CARD ASSEMBLY	C	6,520	84	547,680
69	012343582	CIRCUIT CARD ASSEMBLY	C	4,610	14	64,540
70	012364869	ELECTRONIC COMPONENT	E	4,610	192	885,120
71	012368950	CIRCUIT CARD ASSEMBLY	C	6,610	19	125,590
72	012405410	ENCODER-DECODER, COMPONENT	E	58,760	15	881,400
73	012405638	ELECTRONIC COMPONENT	E	7,230	30	216,900
74	012405661	CIRCUIT CARD ASSEMBLY	C	4,610	51	235,110
75	012417595	CIRCUIT CARD ASSEMBLY	C	9,310	10	93,100
76	012423817	POWER SUPPLY	E	31,690	111	3,517,590
77	012429758	CIRCUIT CARD ASSEMBLY	C	9,740	253	2,464,220
78	012429759	CIRCUIT CARD ASSEMBLY	C	11,960	155	1,853,800
79	012458098	ENCODER-DECODER ASSEMBLY	E	28,410	131	3,721,710
80	012458252	ELECTRONIC COMPONENT	E	4,610	78	359,580
81	012458253	ELECTRONIC COMPONENT	E	5,650	188	1,062,200
82	012458308	CIRCUIT CARD ASSEMBLY	C	4,610	57	262,770
83	012466495	CIRCUIT CARD ASSEMBLY	C	8,680	17	147,560
84	012489228	CIRCUIT CARD ASSEMBLY	C	4,610	170	783,700
85	012517182	VALVE SUBASSEMBLY	M	1,040	26	27,040
86	012517184	TUBE ASSEMBLY, ENVIR	M	18,340	173	3,172,820
87	012567457	ENCODER-DECODER ASSEMBLY	E	79,010	70	5,530,700
88	012613050	CYLINDER ASSEMBLY	M	18,850	44	829,400

#	NIIN	NOMENCLATURE	Class	Std Price (FY2000) Dollars	Completed Repairs 1996-1999	Extended Price (FY2000) Dollars
89	012653660	WHEEL, LANDING GEAR	M	5,880	243	1,428,840
90	012711093	ARM, ACTUATING, HORIZONTAL	M	4,040	13	52,520
91	012718872	CIRCUIT CARD ASSEMBLY	C	6,610	344	2,273,840
92	012727983	ELECTRONIC COMPONEN	E	18,380	177	3,253,260
93	012830299	CIRCUIT CARD ASSEMBLY	C	4,610	22	101,420
94	012917104	POWER SUPPLY	E	8,440	41	346,040
95	012917108	CIRCUIT CARD ASSEMBLY	C	4,610	82	378,020
96	012938970	CIRCUIT CARD ASSEMBLY	C	4,610	135	622,350
97	012938971	CIRCUIT CARD ASSEMBLY	C	4,610	35	161,350
98	012938972	CIRCUIT CARD ASSEMBLY	C	4,610	101	465,610
99	012938973	CIRCUIT CARD ASSEMBLY	C	4,610	209	963,490
100	012938974	CIRCUIT CARD ASSEMBLY	C	4,610	24	110,640
101	012938975	CIRCUIT CARD ASSEMBLY	C	4,610	331	1,525,910
102	012938977	CIRCUIT CARD ASSEMBLY	C	4,610	130	599,300
103	012938979	CIRCUIT CARD ASSEMBLY	C	4,610	6	27,660
104	012938981	CIRCUIT CARD ASSEMBLY	C	4,610	71	327,310
105	012938984	CIRCUIT CARD ASSEMBLY	C	5,890	62	365,180
106	012938987	CIRCUIT CARD ASSEMBLY	C	4,610	147	677,670
107	012938989	CIRCUIT CARD ASSEMBLY	C	4,610	106	488,660
108	012938990	CIRCUIT CARD ASSEMBLY	C	4,610	70	322,700
109	012982165	CIRCUIT CARD ASSEMBLY	C	4,610	89	410,290
110	012990339	CIRCUIT CARD ASSEMBLY	C	6,610	131	865,910
111	012996753	CONTROL, ELECTRONIC	E	49,930	73	3,644,890
112	013009223	INDICATOR, INTEGRATER	E	28,330	43	1,218,190
113	013037755	PANEL, CONTROL, ELECTRICAL	E	15,970	837	13,366,890
114	013042152	CONVERTER UNIT, GENERATOR	E	127,200	147	18,698,400
115	013070911	INDICATOR, VERTICAL	E	2,320	271	628,720
116	013089929	CORE MEMORY UNIT	E	11,340	84	952,560
117	013135202	CIRCUIT CARD ASSEMBLY	C	14,340	71	1,018,140
118	013149770	CIRCUIT CARD ASSEMBLY	C	4,610	110	507,100
119	013161901	ENCODER-DECODER, COM	E	27,280	225	6,138,000
120	013167890	CIRCUIT CARD ASSEMBLY	C	4,610	15	69,150
121	013177764	RUDDER, AIRCRAFT	M	43,220	11	475,420
122	013188983	PANEL, FAULT -FUNCTION	E	26,230	37	970,510
123	013205103	POWER SUPPLY	E	9,020	25	225,500
124	013206599	AMPLIFIER, CONTROL	E	105,490	105	11,076,450
125	013220055	CIRCUIT CARD ASSEMBLY	C	6,610	142	938,620
126	013280481	CIRCUIT CARD ASSEMBLY	C	4,610	62	285,820
127	013289151	CIRCUIT CARD ASSEMBLY	C	6,230	91	566,930
128	013294431	POWER SUPPLY	E	28,250	266	7,514,500
129	013336675	SWEEP GENERATOR	E	19,550	313	6,119,150
130	013336734	PANEL, CONTROL, ELECTRICAL	E	3,890	177	688,530
131	013340998	TANK, FUEL, AIRCRAFT	M	19,140	1	19,140
132	013421499	CIRCUIT CARD ASSEMBLY	C	3,700	13	48,100
133	013432609	INDICATOR, ATTITUDE	E	37,320	1,059	39,521,880

#	NIIN	NOMENCLATURE	Class	Std Price (FY2000) Dollars	Completed Repairs 1996-1999	Extended Price (FY2000) Dollars
134	013437027	CYLINDER ASSEMBLY	M	17,460	44	768,240
135	013438963	CIRCUIT CARD ASSEMBLY	C	9,490	127	1,205,230
136	013438967	CIRCUIT CARD ASSEMBLY	C	7,080	29	205,320
137	013444707	CAMERA, STILL PICTURE	E	86,920	106	9,213,520
138	013475750	CIRCUIT CARD ASSEMBLY	C	5,210	23	119,830
139	013513373	SERVOCYLINDER	M	120,350	1,285	154,649,750
140	013513374	CYLINDER ASSEMBLY	M	44,720	30	1,341,600
141	013555629	CIRCUIT CARD ASSEMBLY	C	5,160	171	882,360
142	013577687	CABLE ASSEMBLY	M	3,610	13	46,930
143	013578862	ELECTRONIC COMPONENT	E	12,660	221	2,797,860
144	013620228	RESERVOIR, HYDRAULIC	M	20,890	79	1,650,310
145	013633416	DRAG BRACE, LANDING	M	21,480	38	816,240
146	013810966	POWER SUPPLY	E	215,110	97	20,865,670
147	991937215	ELECTRONIC COMPONENT	E	27,100	599	16,232,900
148	997578227	CIRCUIT CARD ASSEMBLY	C	11,540	333	3,842,820
149	998421128	CIRCUIT CARD ASSEMBLY	C	3,490	149	520,010
150	999761496	CIRCUIT CARD ASSEMBLY	C	9,560	337	3,221,720
					Total	**752,298,070**

APPENDIX C: TRANSPORTATION AND RTAT DATA ELEMENTS

The following tables define the data elements of the transportation data provided by NAVTRANS, the RTAT data from NAVICP-P and the demand data from NAVICP-P. Each of these data elements provides input into the construction of the total Depot Repair Cycle Time.

Table C.1 NAVTRANS Data Description

Data Field	Data Type	Definition
Julian Date	Date in YDDD format (4)	The date the document number was created by the turn-in activity.
Cognizance Code (COG)	Character (2)	Code that identifies the responsible inventory management organization.
National Item Identification Number (NIIN)	Character (9)	Unique, nine-digit code that identifies each repairable item managed by the NAVICP sites.
Hub Receipt Date (HUBRECVDT)	Date in YDDD format (4)	The date the DLR turn-in was received by the facility directed to receive F condition DLRs and transfer the failed part to the appropriate repair facility.

Table C.2 RTAT Data Description

Data Field	Data Type	Definition
National Item Identification Number (NIIN)	Character (9)	Unique, nine-digit code that identifies each repairable item managed by the NAVICP sites.
Family Group Code (FGC)	Character (4)	Code used to identify similar items belonging to the same family. FGC is blank for non-family items.
Family Relationship Code (FRC)	Character (1), either "H" or "M"	Code used to identify the head of a family. The value "H" is used for family head, and "M" is used for members. FRC is blank for items with no family designation.
Document Number	Character (14)	Code that uniquely identifies each repair transaction.
Serial Number	Character (5)	Code used to uniquely identify different units with the same NIIN.
Quantity (QTY)	Numeric (3)	Quantity repaired per transaction.
Turn Around Time (TAT)	Numeric (3)	Total reported repair time, in days, for each repair transaction. TAT starts when an item is received by the designated overhaul point (DOP) and ends when the DOP transfers the repaired item to a stock point.
Completion Date	Date in YYDDD format	Completion date of repair.
Designated Overhaul Point (DOP)	Character (6)	Code that identifies the site that performed the repair. Six digit codes represent Department of Defense DOPs, known as **organic** DOPs, while three digit codes represent **commercial** (contractor) DOPs.

Data Field	Data Type	Definition
G Time	Numeric (3)	Number of days that the DOP was awaiting parts necessary to complete the repair. If there was no waiting time, G Time is set equal to zero.
Commercial Indicator	Character (1), either “C” or blank	Code that identifies repair transactions that originated from a commercial repair database. Commercial Indicator is set to “C” when this is the case, otherwise it is left blank.
Exclude Indicator	Character (1), either “Z”, “P”, or blank	Code that identifies data recognized by the forecasting tool as either recording errors (Z) or outliers (P) , and thereby excluded from the UICP process. Excluded data are distinguished from “excluded repairable items” for which automated forecasts are not calculated.
Revised Days	Numeric (3)	Set equal to TAT when the record was entered manually, otherwise it is set to zero.

Table C.3 DEMAND Data Description

Data Field	Data Type	Definition
National Item Identification Number (NIIN)	Character (9)	Unique, nine-digit code that identifies each repairable item managed by the NAVICP sites.
Nomenclature	Character	Common name used to identify the DLR item.
Cognizance Code (COG)	Character (2)	Code that identifies the responsible inventory management organization.
Material Control Code (MCC)	Character (1)	Unique one letter code identifying the component either field level or depot level repairable.
Federal Supply Class (FSC)	Character (4)	Unique four-digit code that identifies the federal material category the component would generally be classified under.
Local Routing Code (LRC)	Character (3)	Identifies the NAVICP internal organization responsible for management of the component. A first character of "A" identifies the F/A-18 Hornet airframe NAVICP group.
Quarterly Demand	Numeric	Identifies the forecasted demand developed by the UICP model for the component in the next quarter.
Family Relationship Code (FRC)	Character (1), either "H" or "M"	Code used to identify the head of a family. The value "H" is used for family head, and "M" is used for members. FRC is blank for items with no family designation.
Replacement Price	Numeric	The cost of the component assuming the carcass of the failed component is available for repair and submitted into the Depot Repair Cycle.
Standard Price	Numeric	The cost of a new component or the cost charged to an end user for a component with no available carcass for turn-in.

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